PB 203 959

THE HIGH SULFUR COMBUSTOR

A Study of Systems
for
Coal Refuse Processing

VOLUME TWO
(DESCRIPTIVE DETAIL)

FINAL REPORT
to
DIVISION OF PROCESS CONTROL ENGINEERING
NATIONAL AIR POLLUTION CONTROL ADMINISTRATION
ENVIRONMENTAL HEALTH SERVICE

U.S. DEPARTMENT
of
HEALTH, EDUCATION and WELFARE

CONTRACT NO. CPA 22-69-151

CONSULTING DIVISION
CHEMICO
CHEMICAL CONSTRUCTION CORPORATION
NEW YORK, NEW YORK

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Springfield, Va. 22151

BIBLIOGRAPHIC DATA SHEET	1. Report No. APTD-0769	2.	~~3.~~ Recipient's Accession No.

4. Title and Subtitle
The High Sulfur Combustor
A Study of Systems for Coal Refuse Processing
Volume Two (Descriptive Detail)

5. Report Date
February 1971

6.

7. Author(s)

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Consulting Division
Chemical Construction Corporation
320 Park Avenue
New York, New York 10022

109-5

10. Project/Task/Work Unit No.

11. Contract/Grant No.
CPA 22-69-151

12. Sponsoring Organization Name and Address
Division of Process Control Engineering
National Air Pollution Control Administration
Environmental Health Service
U. S. Department of Health, Education and Welfare
Washington, D. C. 20201

the

13. Type of Report & Period Covered

14.

15. Supplementary Notes DISCLAIMER-This report was furnished to the Office of Air Programs by Consulting Division, Chemical Construction Corporation, 320 Park Avenue, New York, New York 10022 in fulfillment of CPA 22-69-151

16. Abstracts - The purpose of ~~this part of~~ the report is to evaluate certain combustion systems which are designed to make use of high ash, high sulfur reject materials from coal cleaning by means that will generate steam and permit the recovery of sulfur value. Specific compositions of the rejects were not pre-defined. Specifications of the fuels derived from the rejects ("HSC Fuels") have been developed to accommodate the economics or technical limitations imposed by the processes selected. Part XI deals only with the combustors and auxiliaries. The scope of ~~this~~ analysis includes both general and specific design considerations in the following order: ~~1)~~ the HSC Fuel characteristics as determined by variables in composition; 2) suitability of currently available combustion systems to the proposed boiler design, ~~3)~~ specification of the HSC Fuel characteristics required by each combustion system and selection of the combustion system best suited to the process, 4) preparation of conceptual boiler designs and cost estimates for a 500,000 lb/hr. industrial boiler, a 500 MW (megawatt) utility boiler, and a prototype boiler design at 50 MW capacity. Tests and procedures for verifying the HSC Fuel characteristics are recommended. The commercial-scale and prototype designs are developed and cost-estimated according to normal proposal standards. ( )

17. Key Words and Document Analysis. 17a. Descriptors

Air Pollution	Materials recovery
Coal	Fuels
Desulfurization	Combustors
Cleaning	Design criteria
Pyrite	Cost estimates
Sulfur	Cost analysis
Ashes	Combustion

17b. Identifiers/Open-Ended Terms
Air pollution control

17c. COSATI Field/Group 13/B

18. Availability Statement Unlimited A	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 362
	20. Security Class (This Page UNCLASSIFIED	22. Price

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Chemical Construction Corporation
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New York, New York 10022

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HIGH SULFUR COMBUSTOR STUDY

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XI

HSC FUEL SPECIFICATIONS AND COMBUSTOR DESIGN*

1. PURPOSE AND SCOPE

The purpose of this part of the report is to evaluate certain combustion systems which are designed to make use of high ash, high sulfur reject materials from coal cleaning by means that will generate steam and permit the recovery of sulfur value. Specific compositions of the rejects were not pre-defined. Specifications of the fuels derived from the rejects ("HSC Fuels") (identified in this report as "HSC Fuels") have been developed to accommodate the economics or technical limitations imposed by the processes selected. Part XI deals only with the combustors and auxiliaries. The scope of this analysis includes both general and specific design considerations in the following order: 1) the HSC Fuel characteristics as determined by variables in composition, 2) suitability of currently available combustion systems to the proposed boiler design, 3) specification of the HSC Fuel characteristics required by each combustion system and selection of the combustion system best suited to the process, 4) preparation of conceptual boiler designs and cost estimates for a 500,000 lb/hr. industrial boiler, a 500 MW (megawatt) utility boiler, and a prototype boiler design at 50 MW capacity. Tests and procedures for verifying the HSC Fuel characteristics are recommended. The commercial-scale and prototype designs are developed and cost-estimated according to normal proposal standards.

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* Part XI is an adaptation to the format of this Final Report of a report by R.W. Preyers, Foster Wheeler Corporation, of work done specifically for this purpose.

HSC Fuel characteristics are reviewed in Part XI, initially in very broad terms, in an effort to place some limitations on the compositions of the HSC Fuels and to narrow the choice of candidate combustion systems. The selection of the combustion systems is supported by a detailed analysis of the characteristics of coal-pyrite blends derived from information existing in the literature. In order to satisfy the need for additional data and to proceed with the conceptual designs on a reasonable level of confidence, the program was supplemented by a laboratory analysis of various blends of fuels covering the range of HSC Fuel compositions that might be of interest. Finally, a cost analysis of the designs selected is presented, and discussed, in terms of more conventional practice.

2. ANALYTICAL PROCEDURES FOR THE CONTROL OF HSC FUEL SPECIFICATIONS

It has been shown in Volume One, Part IV, that the concentration of pyrite in the HSC Fuels should be contained within a certain range of sulfur to coal ratios (S/C = 0.08 to 2), if steam is to be generated and sulfur value recovered. Ash quantity and composition of the fuel must also be considered with care since in addition to ash of non-pyritic origin each pound of iron pyrite will yield 0.66 pound of ferric oxide ($Fe_2 0_3$). The abnormal quantities and compositions of ash are special factors in fuel preparation, in combustion, erosion control, and fly ash collection. Recommended analytical procedures are described in Part XI-6.

2.1 Ash Softening Temperature

The increased concentration of iron in the ash may well affect the fouling characteristic of the HSC Fuels. This phenomenon is generally best measured by the softening temperature of the ash, that is, the temperature level at which fluid flow[*] becomes plastic or sluggish as a result of a slight decrease in temperature. Ash softening temperature describes the upper limit at which the ash remains pliable or powdery and therefore easily removable from the boiler tubes. Variations in softening temperature can be directly related to the chemistry of the ash component. Ash from bituminous coals consists of seven major constituents: SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, Na_2O, and K_2O. Alumina and silica constitute the major portion of the ash (from 30 to 60%) and are referred to as the acidic constituents; iron is generally the next largest single constituent accounting for 5 to 30%, and is considered to be part of the second group of ingredients called basic constituents. Sodium, potassium, and magnesium are usually present in small quantities only. Calcium can occur in large quantities, but normally does not. The softening temperature of these fuels therefore will be primarily a function of the Fe_2O_3-alumina-silica system characteristics.

Taken together, silica and alumina have a softening temperature well above 2800° F. As basic constituents are added to the mixture, this softening temperature level decreases until a minimum (or eutectic) is reached. At higher Fe_2O_3 concentrations the softening temperature will increase, until a maximum is reached for an entirely basic ash. This effect is illustrated in Figure XI-1, which represents the softening temperatures of non-pyritic ash with extrapolation to high pyritic ash concentrations. The range of critical softening temperatures is dependent on boiler design; for example, in a conventional dry bottom furnace, slagging would be likely to occur on the furnace walls due to a low softening temperature of ash in the 40-60% range of basic constituents. Also, boiler corrosion problems might be encountered as a result of the presence of large quantities of sulfur. In a wet bottom boiler, for example, trouble might arise from ash having an Fe_2O_3 concentration greater or less than these values. In a wet bottom boiler the ash should be thoroughly liquid rather than close to its softening temperature.

---

[*] i. e., "fluid flow" of particles: non-liquid flow.

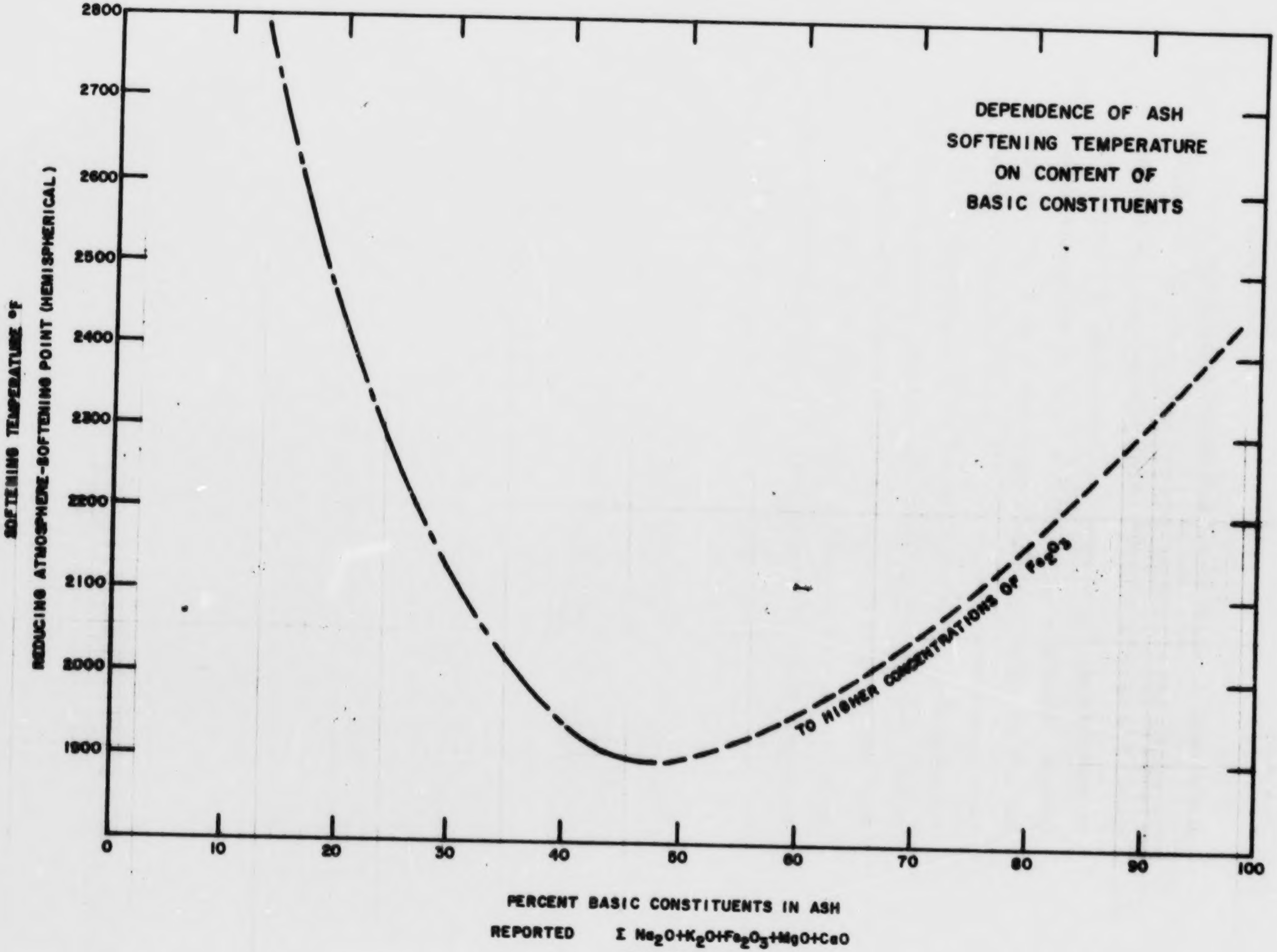

DEPENDENCE OF ASH
SOFTENING TEMPERATURE
ON CONTENT OF
BASIC CONSTITUENTS
SOFTENING TEMPERATURE °F
REDUCING ATMOSPHERE-SOFTENING POINT (HEMISPHERICAL)
2800
2700
2600
2500
2400
2300
2200
2100
2000
1900
0
10
20
30
40
50
60
70
80
90
100
TO HIGHER CONCENTRATIONS OF Fe_2O_3
PERCENT BASIC CONSTITUENTS IN ASH
REPORTED Σ $Na_2O+K_2O+Fe_2O_3+MgO+CaO$

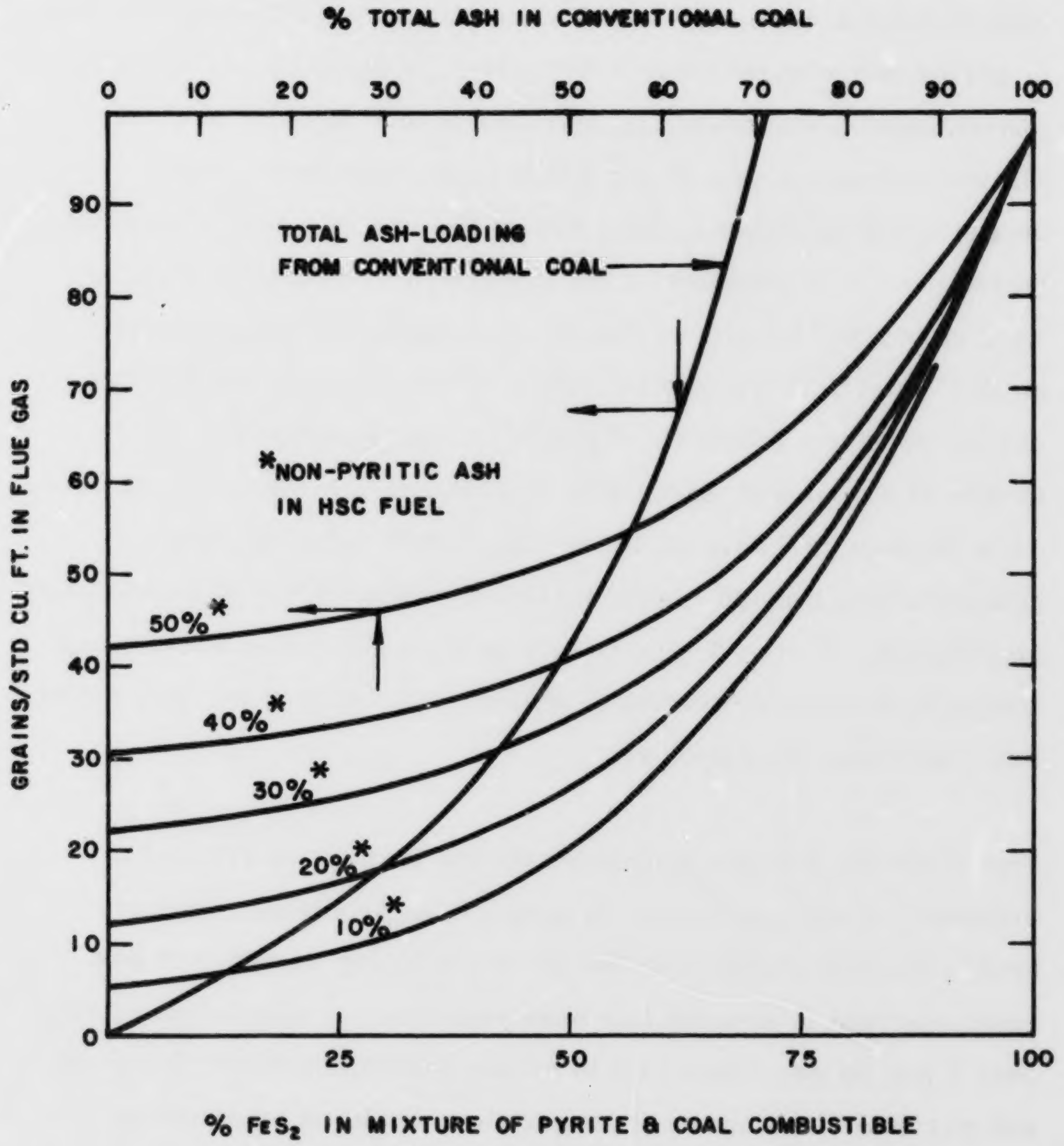
FIGURE XI-1

2.2 Particulate Loading in Combustion Gas

The influence of the total ash on the particulate-loading can be analyzed by first determining the total particulate-loading from pyritic ash at various levels of pyrite concentration in a non-pyritic ash-free HSC Fuel. The effect of non-pyritic ash can then be introduced as an independent variable. The total loading in grains per standard cubic foot will thereupon be comparable to conventional fuels containing various percentages of ash. No allowance has been made for ash lost to the hopper or ash deposited on the tubes, since 80% of the ash in a pulverized fuel boiler generally remains in the combustion products. Figure XI-2 shows the results of this determination and indicates that an HSC Fuel with more than 60% FeS_2 (dry basis) and 20% non-pyritic ash (see Table XI-1) yields an ash-loading equivalent to that of a coal with about 55% total ash in the conventional sense. This level is probably an upper limit from the standpoint of combustion, although higher total ash values of 60-70% have been reported (6, 7, 8). There is still some doubt as to whether the combustion characteristics of a fuel may change when more than 60% inert matter is present.

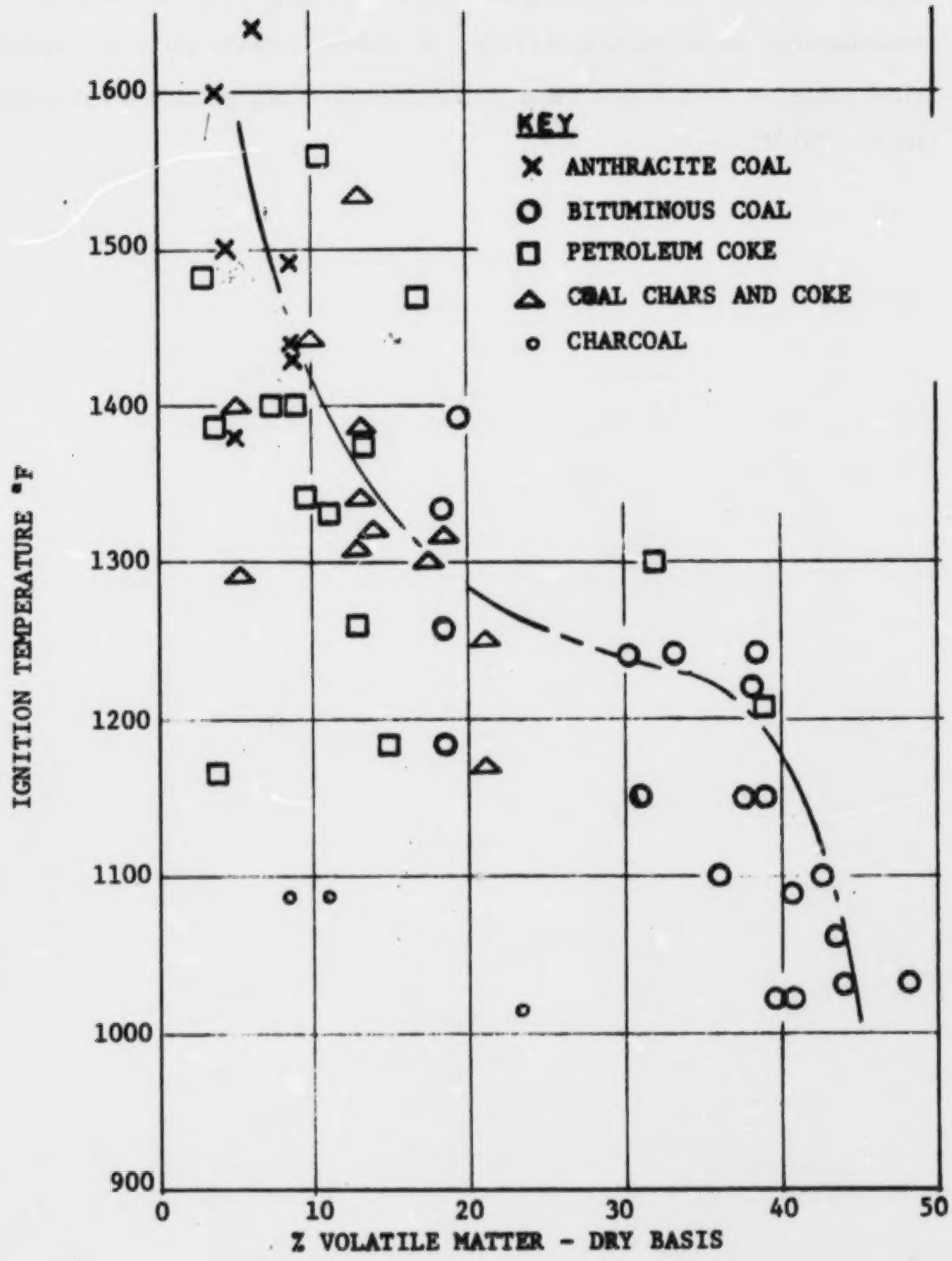
There are no definite guidelines on ash loading as related to erosion. Field experience is limited and problems that have arisen may be peculiar to that specific boiler design. In one case, excessive erosion has been reported for ash-loadings of only 7 grains per cubic foot in refuse plants, possible due to fly-ash particle sizes that are larger than would be expected in

FIGURE XI-2


% TOTAL ASH IN CONVENTIONAL COAL
0
10
20
30
40
50
60
70
80
90
100
GRAINS/STD CU. FT. IN FLUE GAS
90
80
70
60
50
40
30
20
10
0
TOTAL ASH-LOADING
FROM CONVENTIONAL COAL
*NON-PYRITIC ASH
IN HSC FUEL
50%*
40%*
30%*
20%*
10%*
25
50
75
100
% FeS₂ IN MIXTURE OF PYRITE & COAL COMBUSTIBLE

conventional coal boilers, where permissible gas velocities are generally higher. If slag ash particle size is reduced by the added step of fine grinding the fuel, and gas velocities are maintained at moderate levels, it seems reasonable to expect that erosion would not be a criterion for fixing the ash content of the fuels.

FIGURE XI-3



IGNITION TEMPERATURE VS CONTENT OF VOLATILE MATTER FOR VARIOUS FUELS

2.3 Influence of Combustion Characteristics on the Fuel Specifications

The "combustion characteristics" of a fuel generally include heating value, ignition temperature, reactivity, volatility, and percent of fixed carbon. Also grindability, though not a combustion characteristic, is generally considered for economic reasons, along with the others, in evaluating a fuel. Although there is no substantial amount of data that describes the combustion characteristics of blends rich in iron pyrite, there is sufficient information available on pyrite alone to reach conclusions concerning the fuel specifications.

Iron pyrite, frequently considered an inert material when present in small amounts, appears to have combustion characteristics similar to that of a solid fossil fuel. When blended with coal, these characteristics are enhanced. Pyrite has a low ignition temperature, however, around 600° F. which is in contrast to the higher ignition temperatures of conventional solid fuels as shown in Figure XI-3. This low ignition temperature is due to the liberation of one sulfur atom which corresponds to a volatility of about 25% by weight of the pure pyrite. The oxidation reaction proceeds in two steps as follows:

$$\begin{aligned}
FeS_2 &+ \text{Heat} \longrightarrow FeS + S \\
S &+ O_2 \longrightarrow SO_2 + \text{Heat} \\
4FeS &+ 7O_2 \longrightarrow 4SO_2 + 2Fe_2O_3 + \text{Heat}
\end{aligned}$$

The net heat released (heating value of the fuel) is approximately 3000 Btu/lb (9, 12) and less combustion air is required than needed to generate the same heat release from coal. The stoichiometric, adiabatic flame temperature is calculated to be 2300° F; this should be sufficient to sustain combustion, and the presence of bituminous coal will insure it.

The reactivity of the fuel is used as an index of an important combustion characteristic. Essentially, this indicates the temperature at which a substantial increase in the rate of oxidation of the fuel is achieved. The small amount of available information indicates that the percentage of pyrite has a minor effect on the reactivity index of an average coal with fuel compositions as high as 80-90% pyrites. This certainly is reassurance regarding the combustibility of pyrite blends.

2.4 Grindability

Sintered pyrite is reported to have a Grindability Index of 35, which is low as compared to coal which ranges from a low of 45-50 to a high of about 100. This merely indicates that grinding of pyrites to the desired fineness is expected to be expensive.

2.5 HSC Fuel Compositions

The foregoing summary discussion emphasizes some of the important considerations in development of the optimum compromises between the combustor designs and the HSC Fuel specifications. Even so, the specifications proposed here are essentially defined by chemical composition since any valuable options to be found among the physical characteristics of fuels derived from refuse material will be specific to the particular refuse material and will not be amenable to generalization. The chemical compositions, however, must be controlled in respect of two major conditions:

a) The ratio of pyrite to coal combustible (S/C ratio) that will maintain a predicted SO_2 concentration in the flue gas.

b) A total ash of high softening temperature and controlled quantity that will permit dry bottom combustion and a predictable heat release.

The chemical compositions (specifications) of the HSC Fuels necessary to fire the five HSC systems are shown in Table XI-1 following.

TABLE XI-1

HSC Fuel Composition

CASE A	As Received	Moisture Free	Moisture Free Ash Free
	PROXIMIATE ANALYSIS		
Moisture	6.0	--	--
Ash (1)	18.8	20.0	--
Fixed Carbon	10.3	11.0	13.8
Volatile(2)	6.8	7.3	9.2
FeS_2	58.1	61.7	77.0
Total	100.0%	100.0%	100.0%
	ULTIMATE ANALYSIS		
Moisture	6.0	--	--
Ash	18.8	20	--
Total Carbon	13.5	14.4	18.0
Total Hydrogen	0.9	1.0	1.2
Oxygen	2.0	2.2	2.8
Nitrogen	0.5	0.5	0.6
Sulfur	0.3	0.3	0.4
FeS_2	58.0	61.0	77.0
Total	100.0%	100.0%	100.0%
Higher Heating Value		4,424	
	ULTIMATE ANALYSIS (COAL COMPONENT ONLY)		
Moisture	6	--	--
Ash	23.7	25.2(3)	--
Total Carbon	54.8	58.4	78.5
Total Hydrogen	3.6	3.8	4.8
Oxygen	8.8	9.4	12.5
Nitrogen	2.1	2.2	2.8
Sulfur	1.0	1.0	1.4
Total	100.0%	100.0%	100.0%

(1) "Ash" in this tabulation means non-pyritic ash.

(2) Volatile matter as derived from the coal component. One of the S atoms in the FeS_2 is also "volatile" (labile) above about 750° F. Total Volatility may reach 30% of total combustibles in the fuel.

(3) ROM coal may have only 5-10% non-pyritic ash, which may tend to concentrate in the HSC Fuel.

Table XI-1 (Continued)

HSC Fuel Composition

CASE B	PROXIMATE ANALYSIS		
	As Received	Moisture Free	Moisture Free Ash Free
Moisture	6.0	--	--
Ash (1)	18.8	20.0	--
Fixed Carbon	26.1	27.8	34.8
Volatile (2)	17.3	18.4	23.0
FeS_2	31.8	33.8	42.2
Total	100.0%	100.0%	100.0%
	ULTIMATE ANALYSIS		
Moisture	6.0	--	--
Ash	18.8	20.0	--
Total Carbon	34.1	36.3	45.4
Total Hydrogen	2.1	2.2	2.8
Oxygen	5.5	5.8	7.3
Nitrogen	1.2	1.3	1.6
Sulfur	0.5	0.6	0.7
FeS_2	31.8	33.8	42.2
Total	100.0%	100.0%	100.0%
Higher Heating Value		7,400	
	ULTIMATE ANALYSIS (COAL COMPONENT ONLY)		
Moisture	6	--	--
Ash	23.7	25.2(3)	--
Total Carbon	54.8	58.4	78.5
Total Hydrogen	3.6	3.8	4.8
Oxygen	8.8	9.4	12.5
Nitrogen	2.1	2.2	2.8
Sulfur	1.0	1.0	1.4
Total	100.0%	100.0%	100.0%

(1) "Ash" in this tabulation means non-pyritic ash.

(2) Volatile matter as derived from the coal component. One of the S atoms in the FeS_2 is also "volatile" (labile) above about 750° F. Total volatility may reach 34% of total combustibles in this fuel.

(3) ROM coal may have only 5-10% non-pyritic ash, which may tend to concentrate in the HSC Fuel.

Table XI-1 (Continued)

HSC Fuel Composition

CASE C AND D	PROXIMATE ANALYSIS		
	As Received	Moisture Free	Moisture Free Ash Free
Moisture	6.0	--	--
Ash (1)	18.9	20	--
Fixed Carbon	32.6	36.4	44.2
Volatile (2)	21.7	23.5	29.4
FeS_2	19.5	21.1	26.4
Total	100.0%	100.0%	100.0%
	ULTIMATE ANALYSIS		
Moisture	6.0	--	--
Ash	18.9	20	--
Total Carbon	43.0	46	57.5
Total Hydrogen	2.9	3.0	3.7
Oxygen	7.0	7.4	9.2
Nitrogen	1.6	1.7	2.2
Sulfur	.8	.8	1.0
FeS_2	19.8	21.1	26.4
Total	100.0%	100.0%	100.0%
Higher Heating Value		9,000	
	ULTIMATE ANALYSIS (COAL COMPONENT ONLY)		
Moisture	6.0	--	--
Ash	23.7	25.2(3)	--
Total Carbon	54.8	58.4	78.5
Total Hydrogen	3.6	3.8	4.8
Oxygen	8.8	9.4	12.5
Nitrogen	2.1	2.2	2.8
Sulfur	1.0	1.0	1.4
Total	100.0%	100.0%	100.0%

(1) "Ash" in this tabulation means non-pyritic ash.

(2) Volatile matter as derived from the coal component. One of the S atoms in the FeS_2 is also "volatile" (labile) above about 750° F. Total volatility may reach 36% of total combustibles in this fuel.

(3) ROM coal may have only 5-10% non-pyritic ash, which may tend to concentrate in the HSC Fuel.

Table XI-1 (Continued)

HSC Fuel Composition

CASE E	PROXIMATE ANALYSIS		
	As Received	Moisture Free	Moisture Free Ash Free
Moisture	6.0	--	--
Ash (1)	18.8	20.0	--
Fixed Carbon	37.7	40.1	50.1
Volatile (2)	25.1	26.7	33.4
FeS_2	12.4	13.2	16.5
Total	100.0%	100.0%	100.0%
	ULTIMATE ANALYSIS		
Moisture	6.0	--	--
Ash	18.8	20	--
Total Carbon	49.3	52.4	65.5
Total Hydrogen	3.0	3.2	4.0
Oxygen	7.9	8.4	10.5
Nitrogen	1.8	1.9	2.4
Sulfur	0.8	0.9	1.1
FeS_2	12.4	13.2	16.5
Total	100.0%	100.0%	100.0%
Higher Heating Value		9,000	
	ULTIMATE ANALYSIS (COAL COMPONENT ONLY)		
Moisture	6	--	--
Ash	23.7	25.2 (3)	--
Total Carbon	54.8	58.4	78.5
Total Hydrogen	3.6	3.8	4.8
Oxygen	8.8	9.4	4.8
Nitrogen	2.1	2.2	2.8
Sulfur	1.0	1.0	1.4
Total	100.0%	100.0%	100.0%

(1) "Ash" in this tabulation means non-pyritic ash.

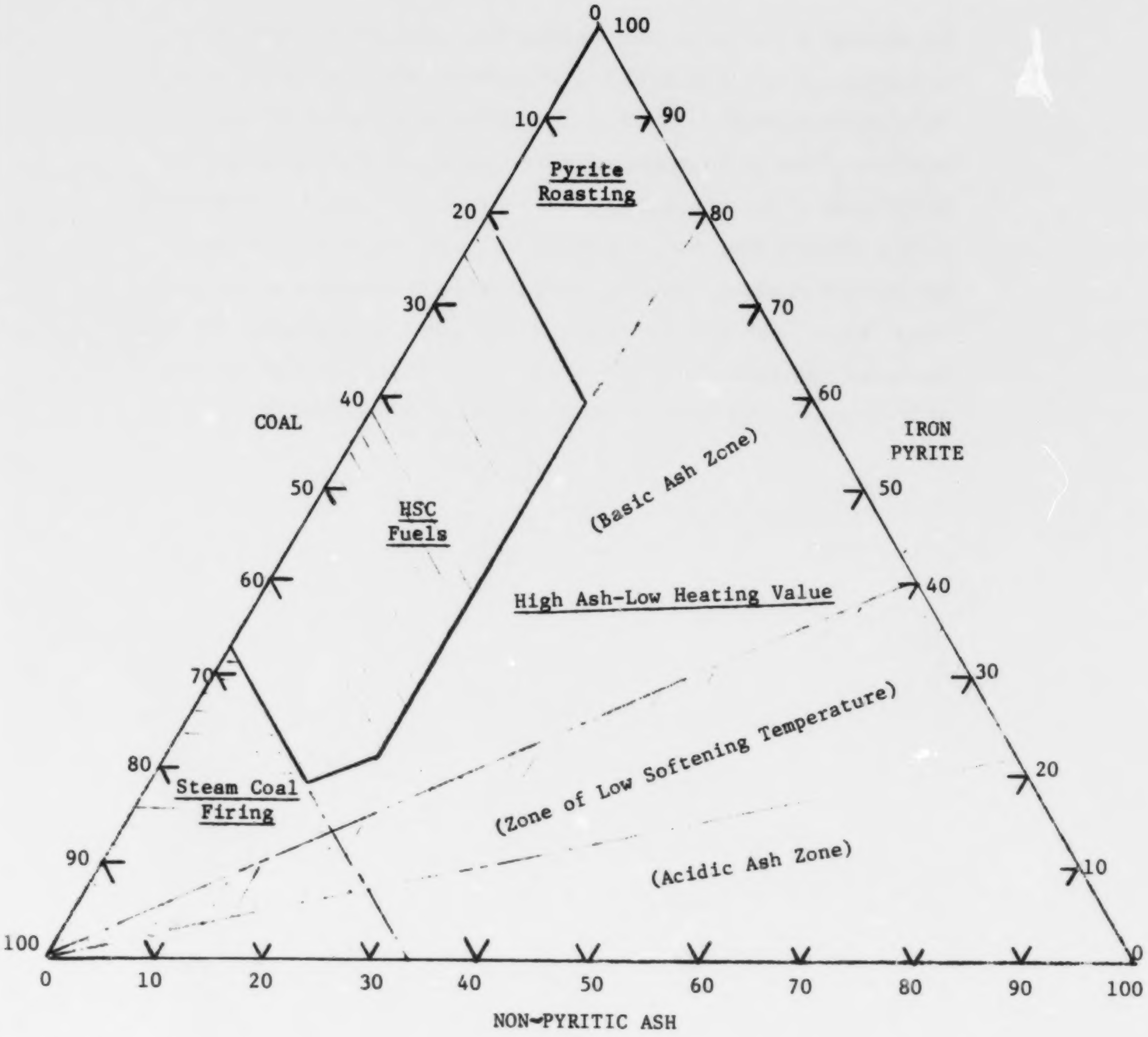
(2) Volatile matter as derived from the coal component. One of the S atoms in the FeS_2 is also "volatile" (labile) above about 750° F. Total volatility may reach 38% of total combustibles in this fuel.

(3) ROM coal may have only 5-10% non-pyritic ash, which may tend to concentrate in the HSC Fuel.

2.6 Coal Combustible Content

An average bituminous composition was selected for the coal component of the HSC Fuel specifications, which we refer to as "coal combustible". The specific limits established for the concentrations of the three major constituents that comprise the HSC Fuels, i.e., non-pyritic ash, pyrite, and coal are displayed on the ternary diagram, Figure XI-4. The diagram illustrates the margin of safety considered desirable to maintain an increasingly "basic" ash with increase in total ash. The diagram reflects the same assumed "average" composition of the non-pyritic ash with respect to its ratio of acidic and basic constituents.

FIGURE XI-4


Pyrite Roasting
COAL
IRON PYRITE
HSC Fuels
(Basic Ash Zone)
High Ash-Low Heating Value
(Zone of Low Softening Temperature)
Steam Coal Firing
(Acidic Ash Zone)
NON-PYRITIC ASH

3. SELECTION OF A COMBUSTION SYSTEM

A number of solid fuel combustion systems were considered as possible means of burning the HSC Fuels. These include:

1. Fluid bed combustion
2. Conventional Pyrite Roasting
    - Rotary Kiln
    - Multi-hearth
    - Flash roasting
3. Cyclone furnace types
    - Pulverized coal
    - Crushed coal
4. Pulverized fuel types
    - Dry bottom furnace
    - Wet bottom furnace
    - Horizontal firing
    - Vertical firing
5. Stoker firing

3.1 Fluid Bed Combustion

Fluid combustion systems are not considered to be readily available since experience is lacking on any scale to be compared with conventional industrial and electric utility steam generators. Even so, it is recognized that fluid processes may ultimately provide the means for handling large quantities of ash at low gas temperatures. The possibility of high temperature corrosion problems and expensive pulverizing of hard material might be avoided by fluidized combustion.

However, an overriding consideration is the uncertain behavior of pyrites in a fluidized bed containing tubes. There is the potential risk of localized sintering which may result from premature quenching of the ash at cool tube surface; the potential of liquid ash may present problems in the design of a bed containing tubes; and, finally, corrosion in the bed could be excessive due to the presence of liquid FeS.

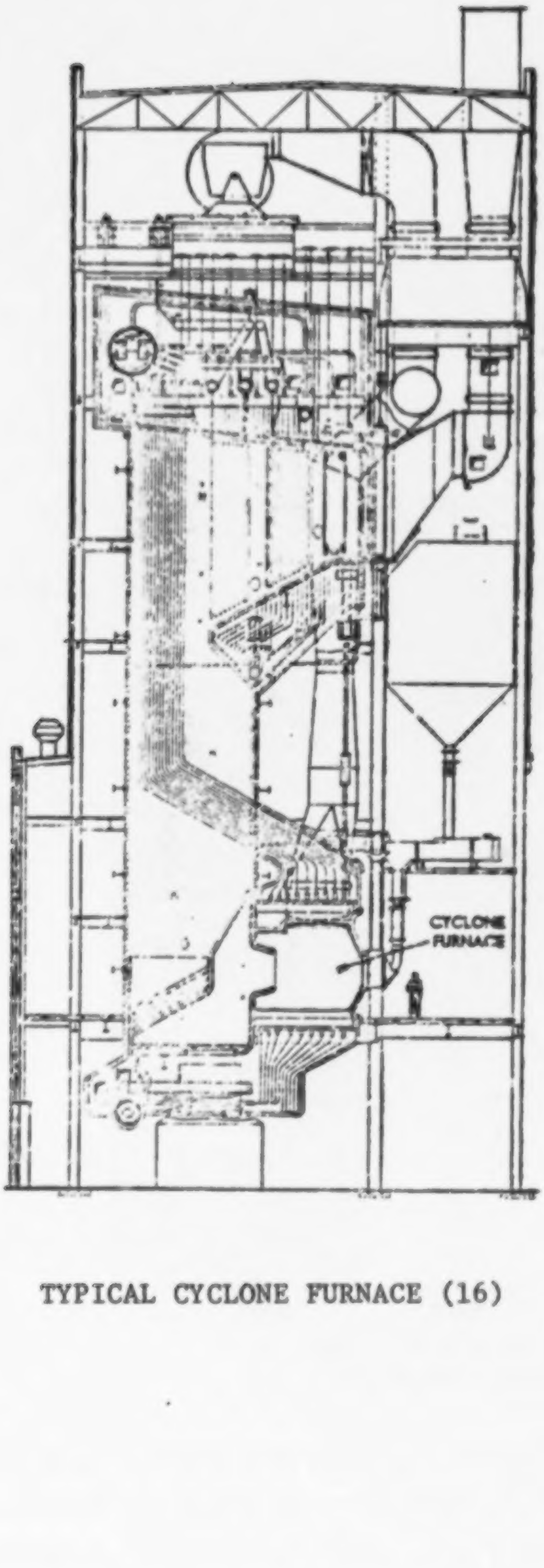
3.2 Conventional Pyrite Roasting Equipment

This method is not acceptable primarily because energy recovery is uneconomical due to low efficiency at the required heat transfer rates.

3.3 Cyclone Furnace Types

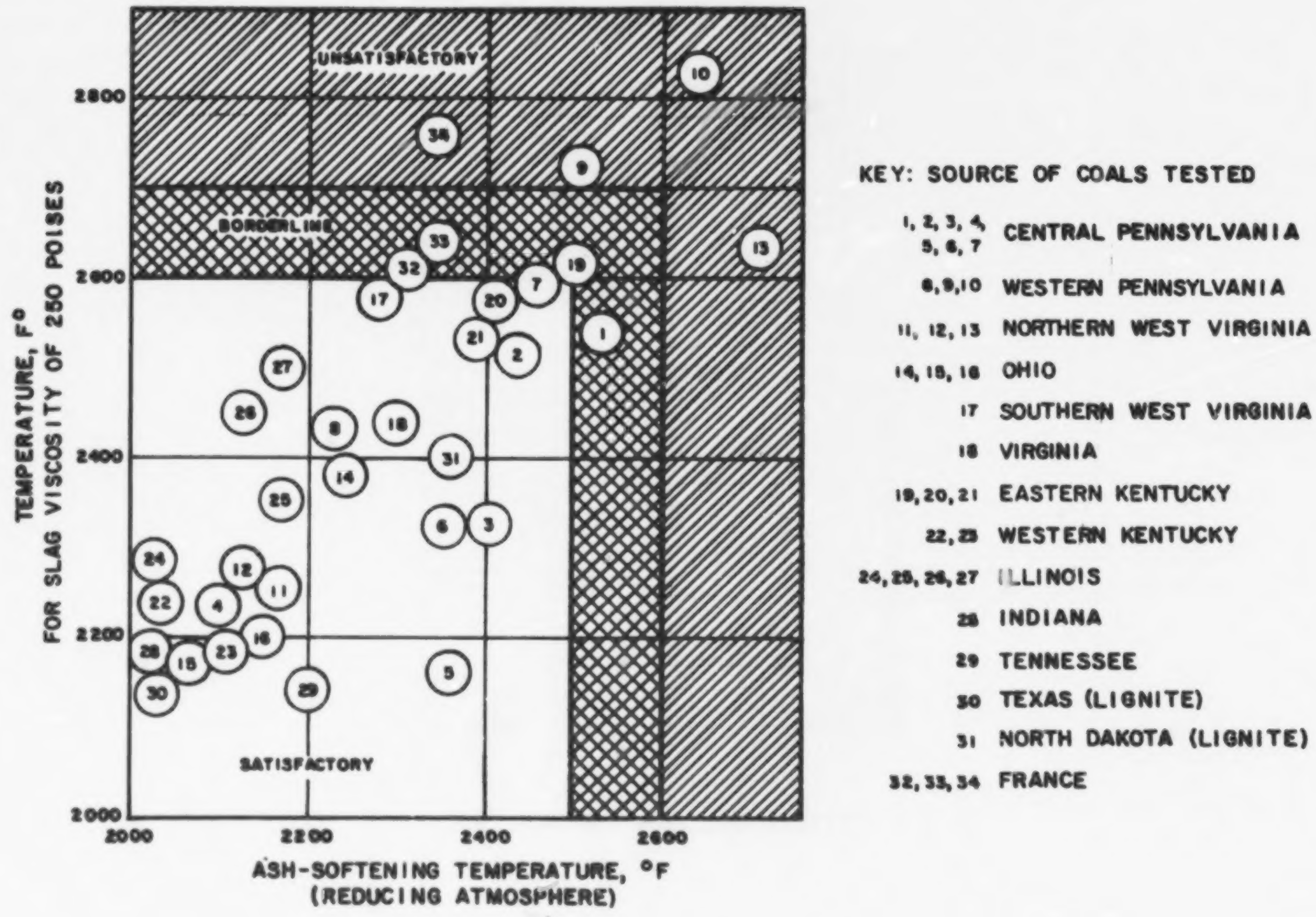
Cyclone furnaces (see Figure XI-5) were rejected because of their record of high maintenance cost, and the likelihood that maintenance problems would be further compounded by firing high iron and high sulfur fuel. Furthermore there is the constant possibility that sulfide formation will occur under local reducing conditions, and the potential corrosion problems could become intolerable, particularly in the case of crushed coal firing, as a result of the tendency of labile sulfur to distill from coarse fuel in the precombustion process and thereafter to condense on cool surfaces with resultant corrosion. Therefore, the major advantage of cyclone furnaces which is the use of coarse coal feed, is diminished to zero. Furthermore, the pyrite-rich fuels may yield an ash of too high a softening temperature for this equipment. Figure XI 6 illustrates the limits normally set for cyclone firing. In order to compensate for this effect, ash would have to be added to the HSC Fuel, or a fluxing agent would be needed, since an improper balance of impurities has been known to cause cyclone furnaces to freeze.

FIGURE XI-5


CYCLONE
FURNACE

TYPICAL CYCLONE FURNACE (16)

FIGURE XI-6



RESULTS OF TESTS ON VARIOUS COALS TO DETERMINE THEIR SUITABILITY IN CYCLONE FURNACE OPERATION (600°F COMBUSTION AIR TEMPERATURE)

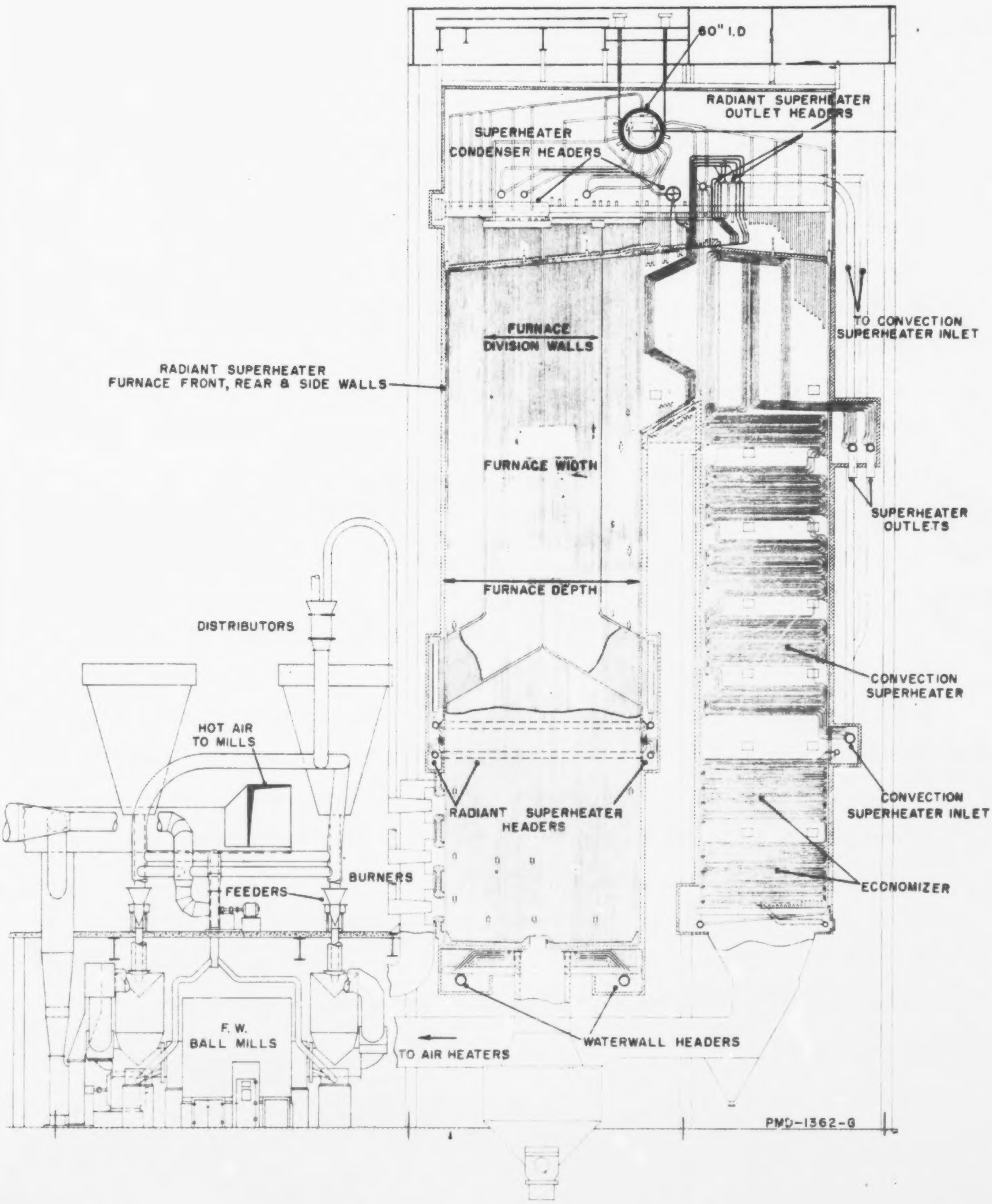
3.4 Pulverized Fuel Types

The same reasoning as above is the basis for elimination of wet bottom boilers as a potential combustion system. Figure XI-7 illustrates a typical wet bottom furnace. The alternative system, suspension firing, with dry ash in either vertical or horizontal position, remains the most likely candidate. The dry bottom boiler, however, is appropriate also because this mode of combustion will probably provide the most reliable operation· it is the least susceptible to corrosion, and can easily achieve the high efficiencies and capacities desired. Dry bottom firing, nevertheless, requires a limitation of the non-pyritic ash content in the HSC Fuels to insure an ash of high softening temperature. The cost of fuel preparation is therefore correspondingly higher.

As to burner configurations, horizontal firing with opposed burners may be used for the low sulfur (CASE C and D) fuel since the deviation from conventional practice is not too great. Opposed firing should provide good mixing and insure complete combustion. The high sulfur (CASE A) fuel with high ash content, and a large percentage of slow burning material, requires special burners fired in the vertical position. This arrangement will permit a long flame path and allow introduction of air along the path of combustion as it is needed. Recent literature describing operations in Belgium on low grade fuels and coal middlings, with low volatility and high ash content, support the choice (6).

Dry bottom boiler equipment is illustrated in Figures XI-60 to XI-65 inclusive.

FIGURE XI-7


60" I.D
RADIANT SUPERHEATER OUTLET HEADERS
SUPERHEATER CONDENSER HEADERS
TO CONVECTION SUPERHEATER INLET
FURNACE DIVISION WALLS
RADIANT SUPERHEATER FURNACE FRONT, REAR & SIDE WALLS
FURNACE WIDTH
SUPERHEATER OUTLETS
FURNACE DEPTH
DISTRIBUTORS
CONVECTION SUPERHEATER
HOT AIR TO MILLS
CONVECTION SUPERHEATER INLET
RADIANT SUPERHEATER HEADERS
BURNERS
FEEDERS
ECONOMIZER
F. W. BALL MILLS
WATERWALL HEADERS
TO AIR HEATERS
PMD-1362-G

TYPICAL WET BOTTOM FURNACE

3.5 Stoker Firing Types

Stoker firing of residual fuel is not feasible strictly because of capacity limitations since for the steam conditions under consideration, the stoker-fired, grate-type furnaces cannot be built for the necessary heat-rates.

4. DISCUSSION OF FUEL CHARACTERISTICS

The HSC Fuel specifications were discussed in Part XI-2, in order to determine the variables most important in selecting the combustion process, and to allow the preliminary combustor design work to begin. The HSC Fuel characteristics were dictated by the character of pyrite-bearing steam-coals, by available SO_2 recovery technology, by the chemistry of fuel ash and, to a lesser extent, by the limitations that may be imposed by good combustor design and operation. The first synthesis of the fuel specifications was directed towards fixing the proximate analysis of the fuel and selecting a range of values for the carbon/sulfur ratio.

Now, specific fuel characteristics will be reviewed in order to determine the effect of the various fuel properties on boiler design so that a range of permissible values may be set where necessary; also to indicate when tests may be required to insure that the fuel qualities permit proper boiler operation.

These fuel characteristics will, in turn, affect pretreatment of the HSC Fuel, combustion, fouling, and, to a lesser extent, erosion and flyash discharge. Except for the carbon to sulfur ratio and the non-pyritic ash and total ash, the proximate and ultimate analyses of these fuels need not be considered further. The physical characteristics that will be discussed include the Hardgrove grindability, abrasion index, heating value, ignition index, reactivity, volatility, ash content, and ash chemistry. The subjects will be related to the overall composition of the fuel which may be considered to consist of three basic constituents: 1) coal combustibles, i.e., carbon, hydrogen, etc., 2) sulfur, and 3) ash.

The HSC Fuels contain large quantities of pyrite. Data on the characteristics of blends of coal and pyrite are not readily available. Therefore, it was necessary to run a series of tests on selected blends of pyrite, ash, and coal in the laboratory to determine how the fuel characteristics might be expected to vary. The tests were expected to show up any peculiar behavior of the fuels resulting from changes in composition.

The laboratory program consisted of blending Pocahontas No. 3 coal with almost 100% pure pyrite, generated in a coal cleaning process at the Bruceton Laboratories of the U.S. Bureau of Mines, together with selected specimens of ash deposits from boilers. Pocahontas No. 3 coal was chosen primarily for its low ash content in order to simplify the blending of the three basic constituents. The ash was rich in alumina and silica. The chemical analyses for samples "A" and "B" appear in Table XI-2. Blends of this were made with the coal and pyrite to simulate a variety of compositions in the range of interest. Ash was combined with several blends of coal and pyrite at three different levels especially to indicate the effect of the inert matter. (See Table XI-3).

A complete conventional coal analysis was made on all the samples including proximate analysis, ultimate analysis, Hardgrove index, reactivity, heating value, and ash fusion tests. The data are tabulated in Appendix D of Part XI and discussed under the appropriate sections below.

TABLE XI-2†

Chemical Composition of Ash Samples "A" & "B" Blended With Coal and Pyrites

Chemical Constituent	Sample A	Sample B
Al_2O_3	15.0	14.5
SiO_2	25.0	17.0
TiO	0.50	0.8
Fe_2O_3	8.5	3.25
CaO	28.5	13.0
K_2O	0.48	6.88
Na_2O	3.6	3.37
MgO	7.4	3.19
P_2O_5	3.45	0.57
SO_3	10.0	32.17

Ash Fusion	"A"	"B"
Reducing Atmosphere		
Initial Deformation	2240	2380
Softening Temperature	2350	2440
Fluid Temperature	2600	2560

Sample A was mixed with blends; 2A, 2B, 2C, *
3A, 3B, 3C,
4A, 4B, 4C

Sample B was mixed with blends; 1A, 1B, 1C,
5A, 5B, 5C.

* See Table XI-3

† SEE APPENDIX XI-D FOR DETAILS OF THESE COMPOSITIONS

TABLE XI-3 †

Final Composition of HSC Fuel Blends

	Percent				
Sample Number	Ash (4)	Pyrites (1)	Coal	Total Ash (3)	
1A (2)	32.5	16.5	51	36.4	■ *
1B	27	17	56	29.7	⬡
1C	34	14	52	35.8	▲
2A	19	35	46	39.1	■
2B	27	32	41	50.4	⬡
2C	34	29	37	53.4	▲
3A	20	50	30	54.8	■
3B	28	45	27	58.0	⬡
3C	35	40	25	65.6	▲
4A	17	66	17	61.6	■
4B	28	57	15	67.3	⬡
4C	35	51	14	71.2	▲
5A	5	80	15	55.3	⌓
5B	10	76	14	55.1	◆
5C	15	71	14	58.0	■

(1) Percent includes small quantities of ash and carbon left in cleaned pyrites. Refer to analysis of cleaned pyrites.

(2) An error was made in the initial blending of the ash.

(3) Non pyritic ash plus pyritic ash as analyzed.

(4) Non pyritic ash.

* Symbols appearing on graphs and data sheets.

† SEE APPENDIX XI-D FOR DETAILS OF THESE COMPOSITIONS

4.1 Pretreatment of Coal

Since physical handling of coal prior to combustion includes grinding and pneumatic transport, certain fuel characteristics are of principal concern at this initial stage and these include:

a) Initial size

b) Moisture and sulfur content

c) Specific gravity

d) Grindability

e) Abrasion index

4.1.1 Initial Size

The HSC Fuel received at the generating station will be sized according to the fineness needed for the separation of pyrite and ash from coal in the cleaning operation. This fineness will be influenced by the size of the pyrite nodules in the raw coal, the permissible carbon loss during the coal cleaning process, and other factors, such as windloss in transportation. Then, in turn, the size of the HSC Fuel affects the mode of storage and conveyance, the cost of maintenance, and the power needed to grind to pulverized specifications.

Saltsman (13) and Glenn (14) report that pyrite occurs in coal as discrete particles in a wide variety of shapes and sizes of which the principal forms are:

i) Rounded masses, called sulfur balls or nodules, which range from fractions of an inch to very large masses.

ii) Lens-shaped masses which may be thought of as flattened sulfur balls and vary greatly in thickness and dimension.

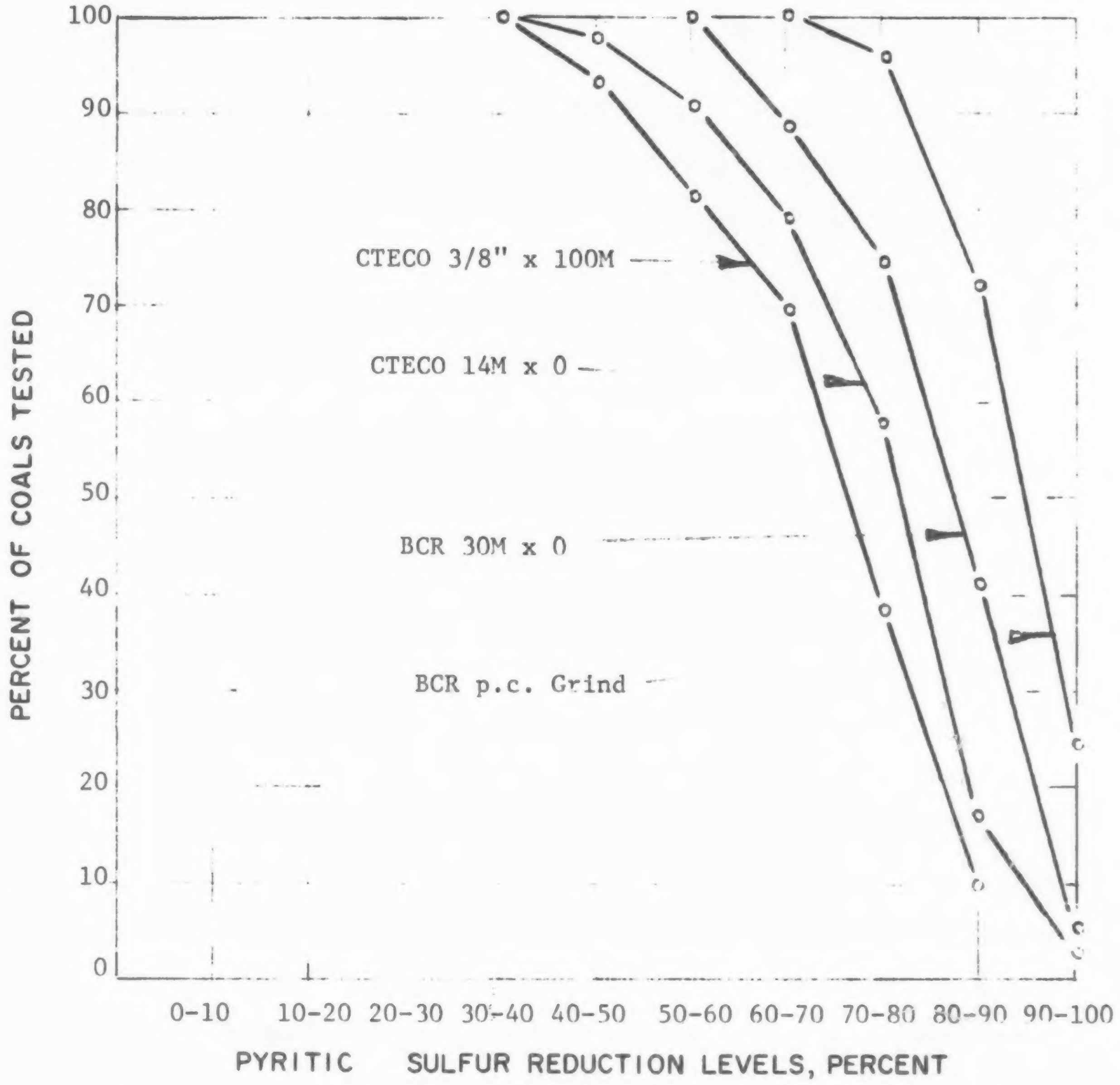
iii) Veins of pyrite consisting of vertical or inclined veins or fissures filled with pyrite and ranging in thickness up to several inches.

iv) Small discontinuous veinlets of pyrite, many of which radiate from a common center which may be a small sulfur ball.

The degree of liberation of pyrite from coals varies greatly among coals; in some coals, the pyrite is so finely divided that little liberation occurs when the coal is pulverized to conventional size (60 to 85% under 200 mesh).

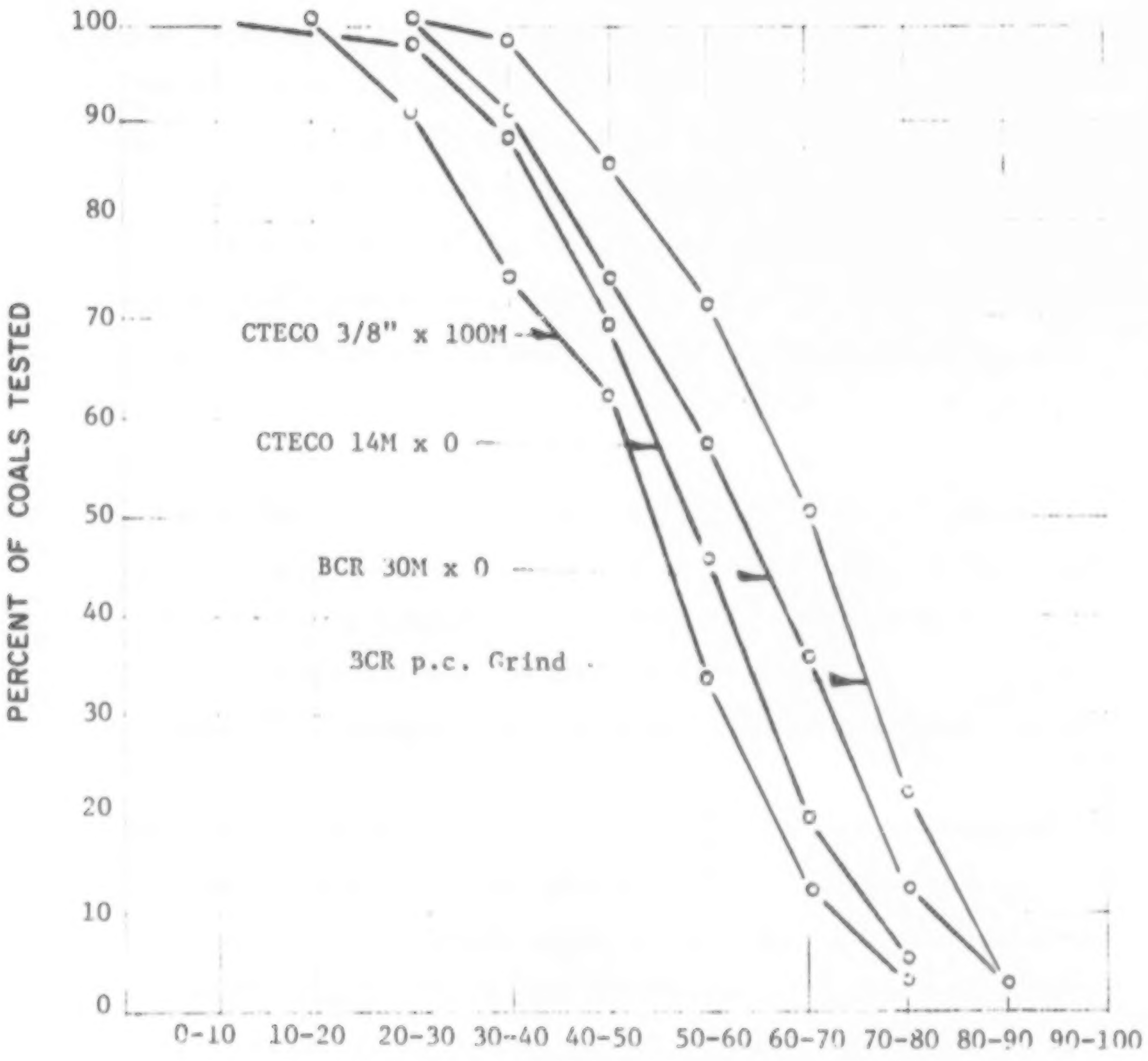
In a study of sulfur reduction at 1.60 specific gravity (as related to nominal top size of this coal) of many different coals, it was found that, on the average, a 50% reduction in pyrite occurred in at least one-half of the coals tested, using a 3/8" x 100 mesh size. Greater reductions in a larger percentage of the coal could be achieved by treating finer sizes of coal. The results are summarized in Figures XI - 8 and XI - 9 and indicate the pyritic and total sulfur reduction achievable at various finenesses for various percentages of coals tested. It can be concluded that 3/8"

FIGURE XI-8



PYRITIC SULFUR REDUCTION AT 1.60 SPECIFIC GRAVITY
AS RELATED TO NOMINAL TOP SIZE OF COAL (13)

FIGURE XI-9



TOTAL SULFUR REDUCTION AT 1.60 SPECIFIC GRAVITY
AS RELATED TO NOMINAL TOP SIZE OF COAL (13)

x 100 mesh is the largest reasonable size that may be expected from a coal cleaning operation.

Sizes smaller than 3/8" x 100 mesh may introduce handling problems that could be of overriding concern, since there is strong feeling that finely pulverized coal cannot be transported in open vehicles. Thus, an additional cost for enclosure or preparation for shipment would be incurred and added to total cost of processing the fuel. A report by Arthur D. Little, Inc. (15) indicated that one electric utility station received 10 mesh coal from a metallurgical coal processing plant, shipped a short distance in open hopper cars and covered by a layer of screened coal. Handling problems at the boiler were minimized by blending one car of fine coal with two cars of screened coal. This procedure may solve the transporting problems, but also may further complicate the economics with the requirement for further blending. In addition, increasing the fines increases the maintenance problems, increases the fire hazards, and introduces the possibility of dust explosions.

Storage of coal in a bin or open field requires that coal sizes be limited between 1/2" and 1-1/4" to avoid spontaneous combustion of the raw fuel; freshly mined coal is subject to rapid oxidation at temperatures only slightly higher than ambient, and the potential fire hazard is compounded by the presence of pyrites and moisture. In the presence of water, FeS_2 unites with oxygen to form $FeSO_2$ and sulfuric acid, liberating heat and eventually causing fire. Safe outside storage of coal necessitates the unrestricted flow of air throughout the site to remove any heat of oxidation as rapidly as possible; or that air flow within the site is totally stopped, thus limiting the oxidation process. Therefore, it is very important to avoid segregation by particle size resulting in air flow being unrestricted in some areas and not in others, which would cause overheating.

Internal storage, or bunkering within the power station is essential to maintain the continuous operation of the power generating equipment. A system pressurized with inert gas is often required for internal storage of pulverized coal, but complicates handling, requires close monitoring of temperature, and higher initial investment and operating cost.

An initial reduction in ROM size from 3/8" x 100 to 30 mesh x 0 may result in better cleaning to compensate for grinding cost, and additional grinding of the derived HSC Fuel will be unnecessary. However, the problems in transporting fine particle size materials must be balanced against cost savings achieved at the power plant; less work must be done to reduce the size of the fuel to the final state required for combustion. It seems reasonable to assume that the initial HSC Fuel size of 3/8" x 100 is satisfactory for the purposes of design. If further work should reveal that another size is more appropriate, design changes can be made in the final plant without much difficulty.

4.1.2 Moisture and Sulfur

Moisture content in the coal should be minimized to prevent caking, excessive transportation cost, and to reduce safety hazards in the storage area. There is evidence that moisture would probably be 3% in the HSC Fuel if it is thermally dried after the cleaning operation. This value should be taken as an average since levels as high as 6% may occur.

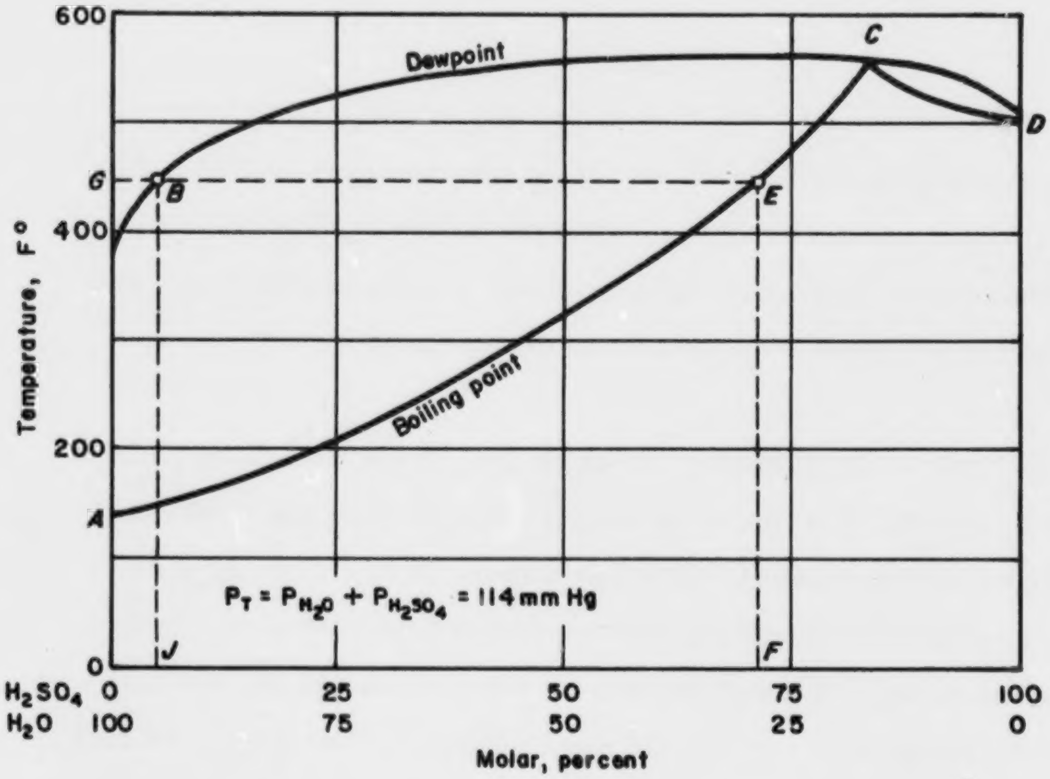
In the case of conventional steam coal, the moisture level might have a significant effect on the dewpoint of the boiler flue gas. But at the high level of sulfur oxides in the flue gas under consideration, the dewpoint is already very high and therefore insensitive to reduction in moisture level. This is clearly illustrated by the phase diagram for the sulfuric acid-water system in Figure XI-10.

Other parameters influenced by moisture content are mill capacity, corrosion rates at low temperature during the coal handling process, and preheated air drying requirements; these must be balanced by a compromise of economics and engineering design. However, the moisture level is already low and further reduction will probably not be warranted.

4.1.3 Specific Gravity

The specific gravity of ROM coal is normally about 1.3. After various separations by sink-float procedures, the specific gravity of the HSC Fuels can be expected to increase to a value in the range 1.60 to 2.90 depending upon the

FIGURE XI-10



DEWPOINT AND BOILING POINT CURVES
FOR THE SULFURIC ACID-WATER SYSTEM

concentration of iron pyrite (which will have a specific gravity as high as 5.0) and coal and ash particles (of specific gravity of 1.3 and 2.9 respectively). This wide range of specific gravities will affect the classification of material at the mill; since the grindability of the heavier particles is low, the mill will be required to handle large quantities of stored, that is, recycling, pyrites.

4.1.4 Grindability

This characteristic of the fuel is usually measured in terms of grindability index, which is not an inherent property of the fuel but depends on the type of apparatus used. Therefore, this index must be established by some standard technique and interpreted for each type of available equipment.

The Hardgrove Grindability Index is the ASTM standard and is widely used. The Index is determined by placing a 50 gm sample of air-dried fuel, sized to minus 16 and plus 30 mesh in the mortar of the testing machine together with some one-inch steel balls. A weighted upper race is placed on the ball and fuel charge and run for 60 revolutions. The sample is then removed and screened. The quantity passing through the 200 mesh sieve determines the grindability index according to the following empirical equation:

$$G = (\text{Grindability}) = 6.93\,W + 13$$

where W is the weight in grams of that portion of the sample passing through the 200 mesh sieve. Further details of this test are described in ASTM-D409-51.

The Grindability Index of the fuel does not determine the mill capacity; mill design is based on other factors such as initial fuel size, final fuel size, and moisture. The first two factors obviously affect the amount of work that must be done on the fuel, and the residence time that is required to achieve a desired fineness. Moisture, particularly surface moisture, adversely affects the grinding process by producing agglomeration of fines in the pulverizing zone, thereby reducing the efficiency of the process by which the pulverized material is removed. To compensate for this, the residence time must be increased, requiring an increase in storage capacity of the mill and lowering its effective grinding capability.

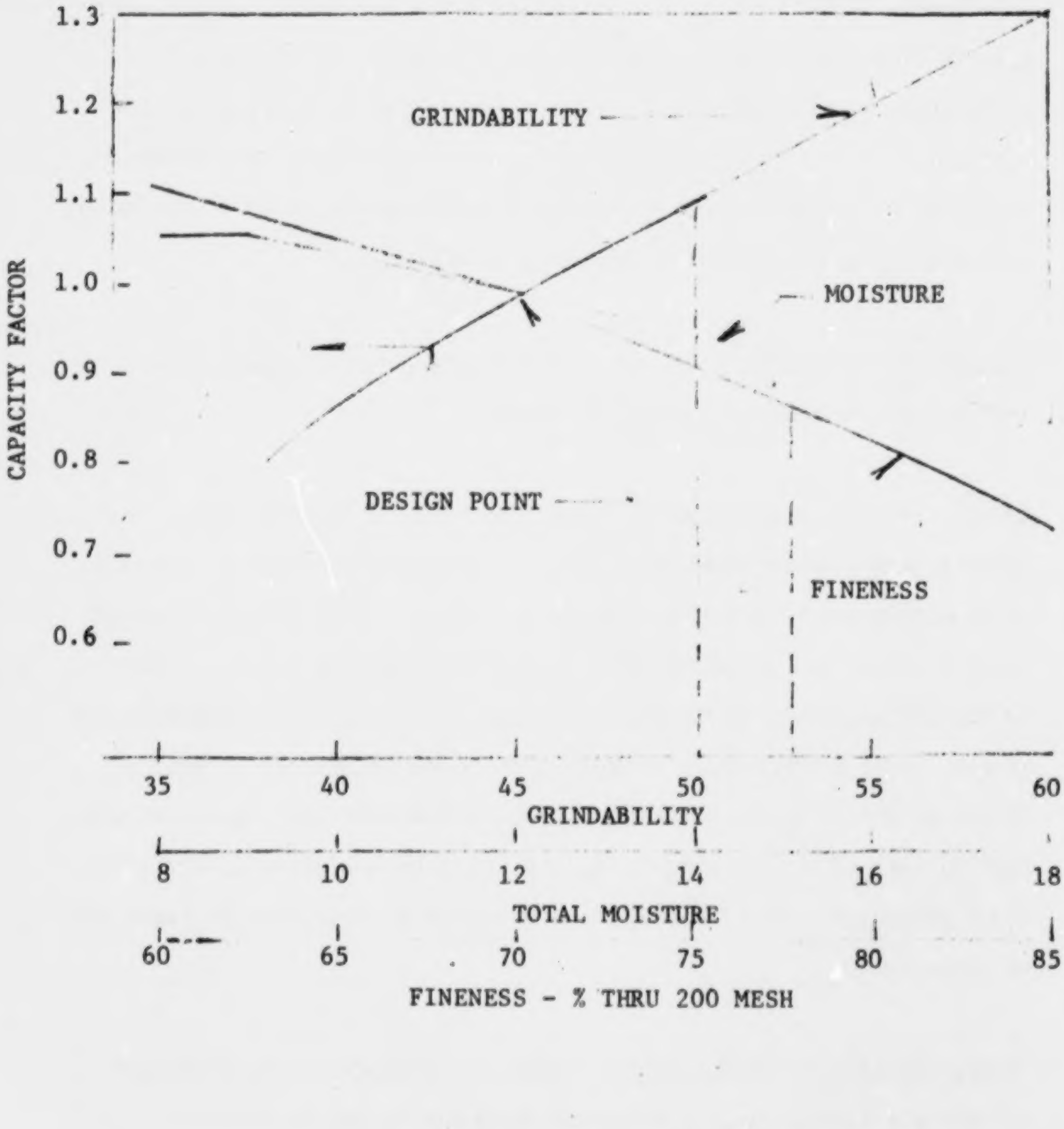
Figure XI-11 illustrates the relationship of mill capacity vs. moisture, grindability, and fineness.

Since the fuel under consideration is a blend of coal, ash, and pyrite, each constituent has its own grindability index, though coal displays the greatest range of values. The grindability of coal in this case may be 50-110, which appears to be similar to the grindability of moderately high sulfur Eastern bituminous coals. The grindability of ash is considerably lower, but its index is not of great importance since the tolerable level of non-pyritic ash in the process must be fixed by considerations other than grinding. The Grindability Index of pure pyrite is expected to be about 35.

The grindability of the blend, however, cannot be determined by simply calculating a weighted average of the individual

FIGURE XI-11

TYPICAL CAPACITY FACTOR CURVE
FOR A RING AND ROLL MILL



EFFECT OF MOISTURE, GRINDABILITY
AND COAL FINENESS ON MILL SIZE

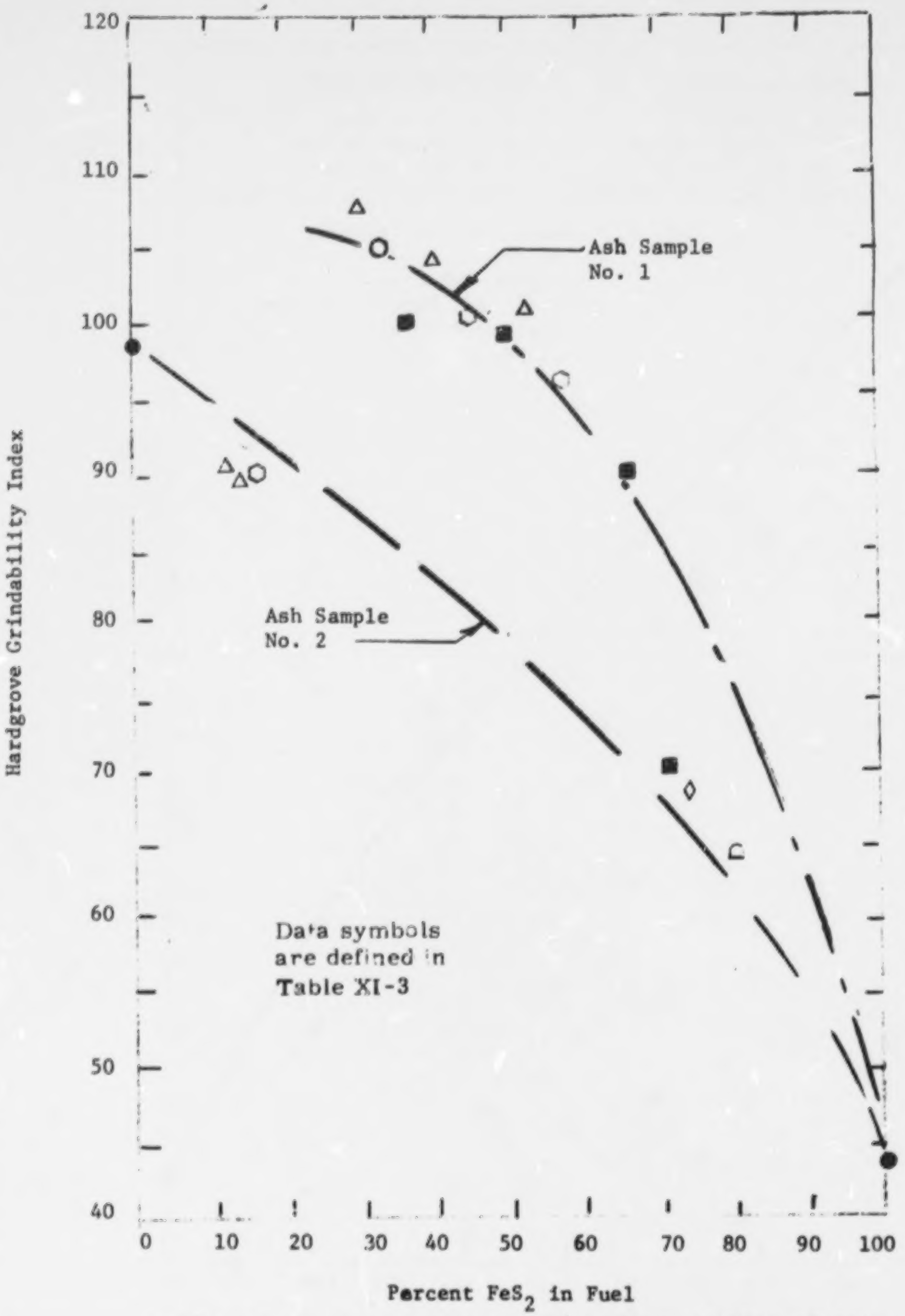
grindabilities. During the process of grinding, each constituent will be reduced at a different rate, i.e., the "soft" material with a high Grindability Index will be reduced first. In actual mill operation, the soft fines will be removed, leaving a mixture rich in harder particles. The proportion of hard material will increase until equilibrium between the mass stored or recycled and the mass passing through the mill is reached; at this point, the mill may be "flooded" by pyrite. One source reports that the residence time of pyrite is seven times that of coal in the mill (17). Generally speaking, estimates of the grindability of various compositions must be based on operating data. A literature review did not uncover any data relevant to the compositions being considered. The Illinois Geological Survey has indicated that the Hardgrove Index for Illinois coal float fractions at specific gravity 1.60 was about 64, with a maximum deviation of about 11 (18). This datum is for a coal of low pyrite and ash content. But the specific gravity of the test fraction in this instance is too low to draw conclusions concerning the HSC Fuels. In the absence of adequate published data, and as a first step to full-scale tests, it was decided that laboratory tests of blended mixtures were essential.

Accordingly, tests were run with various blends of coal, pyrite, and ash, detailed in Table XI-3, according to ASTM procedure. The pyrite used in blending was produced by beneficiating the tailing from a coal cleaning operation. Testing was complicated by the fact that the pyrite was already reduced to a size below that normally described in the ASTM procedure. Therefore, the results must be corrected for this reduced feed size by using an appropriate extrapolation. The raw data appear in Figure XI-12 ; the corrected data, with a sample extrapolation appearing in the insert, are illustrated in Figure XI-13.

The data indicate that the grindability of the blends cannot be assumed to be a linear function of the pyrite concentration. The grindability remains relatively constant up to about 50% pyrite concentration and then it drops sharply. Considering the hardness of pyrite, it seems reasonable to expect that the grindability would decrease rapidly at first and eventually approach a lower limit as the pyrite becomes the primary constituent. The behavior of the grindability data may result from the increase in effective grinding capacity of the mill with the introduction of a second extremely hard component. It is possible that a greater quantity of soft material can be broken down or reduced to a smaller size by the abrasive irregularly shaped pyrite when the latter is introduced in small quantities. Reduction in size of the pyrite may be postponed until the soft material is completely reduced. For those cases in which the predominant phase is pyritic, the total quantity of material reduced is small. The test results tend to confirm this last supposition. Ash appears to have little influence on the Grindability Index up to 35% by weight.

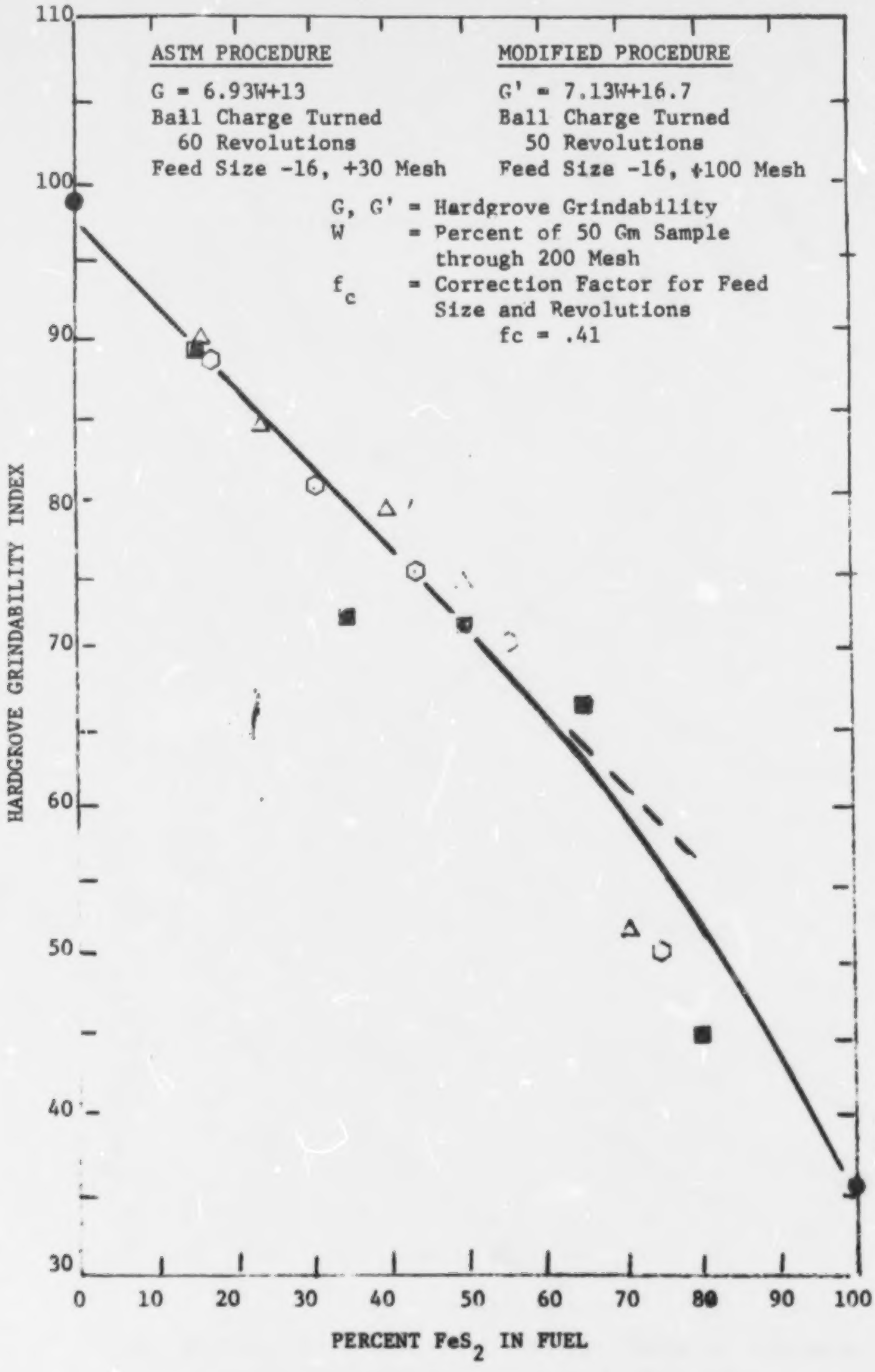
Since the Hardgrove test is only based upon 60 revolutions and the grindability index of the pyrite phase is low, the necessary reduction in size will take considerably longer. Therefore the mill will tend to flood at the lower value of pyrite

FIGURE XI-12



HARDGROVE GRINDABILITY FOR EXPERIMENTAL BLENDS OF COAL AND PYRITE VS PYRITE CONCENTRATION

HARDGROVE GRINDABILITY OF BLENDS OF COAL AND PYRITES
VERSUS
PYRITE COMPOSITION CORRECTED FOR FEED SIZE REDUCTION AND GRINDING TIME REDUCTION



concentration. In sizing the mill, lower grindability indices should be used to arrive at a capacity sufficient to handle the additional pyrite that will be recycled during the milling operation. At the higher levels of pyritic concentration, a larger proportion of the pyrite is being ground during the grindability test. Therefore, the index probably approaches the true value of the grindability of the mixture. It is recommended for development of design data that further laboratory testing be done on full scale equipment with various HSC Fuels of different grindability indices.

4.1.5 Abrasion

The influence of abrasion on combustor design is difficult to evaluate since standard tests have not yet been developed for coal, and the data appearing in the literature can only be utilized as relative orders of magnitude. Due to the lack of quantitative data, a review of some generalizations about coal, ash, and pyrite is necessary to provide an insight into the process of material selection, sizing, and maintenance cost estimates.

Wearing of metal, due to forcible contact with other materials can be classified as wear due to the friction between the metal and materials softer than the metal, and, conversely, wear due to the cutting, gouging, or shearing action on the metal by materials having greater hardness. The abrasion caused by cutting is far more rapid than that produced by friction alone but the mechanism of shear-displacement of the crystals in the metal is the same and occurs in each type of abrasion. The effects of the abrading material, whether softer or harder than the metal, depend mainly on the relative hardness of each, and apply for both the frictional and cutting types of wear. As the hardness of a softer material approaches the hardness of the metal, the more shear-displacement of the crystals will result. As the hardness of the abrading material increases above that of the metal, the more rapid becomes the cutting action on the metal.

The complex resistance to sliding or shear-displacement is found both in the materials cut and in the cutter materials since the latter differs mainly in its superior hardness. In commercial cutting operations certain hardness relations between the cutter and the material being cut must be maintained. It was found that the relation of 2 to 1 in hardness (measured in Shere's aderoscope scale) will permit a slight cutting without instant loss of edge of the cutter. A hardness ratio of at least 2.5 to 1 is necessary to preserve a keen edge for a short time, while a minimum hardness relationship of 3 to 1 is essential if the cutter is to function as a standard tool (19).

According to Haywood (20), the resistance of coal to grinding in order of increasing resistance is as follows: fusion 0.47; very bright coal 1.00; streaked coal 1.50; and dull coal 2.18. Impurities such as Kaolin, shale, sandstone, silica, calcite, and pyrite, have very different characteristics; pyrite and silica are much harder than coal, and almost all the other impurities are also harder but to a lesser extent. Therefore, the impurities are the cause of the major portion of abrasion from coal. Since theory indicates that hardness is related to abrasion as well as to grindability, this quality may be used as an index. The resistance of a smooth plane surface to abrasion is called its hardness and is commonly classified for 10 standard minerals according to Mohr's scale as shown in Table XI-4. Some common materials rated by Mohr's hardness scale are listed in Table XI-5, but such figures are only relative and tell little about solid fuels for practical purposes.

Parton, Paciotti, and Delaney (19, 21, 22) investigated the abrasive characteristics of coal, and after reviewing the tests used to evaluate abrasion from various materials,. they concluded that none would meet completely the test requirements for solid fuels. Accordingly, a test was devised as follows: a sample of minus 10 plus 200 mesh coal provides the abrasive attack on an iron test piece used to measure the wear, and wear is produced by actually pulverizing the sample with the test piece. The procedure is to revolve the test piece for a fixed number of times at a constant thrust against the coal sample. The pulverized coal is removed from the cylindrical mortar by compressed air, thereby allowing the test disc to come continually in contact with fresh coal. The loss in weight of the disc is the fundamental value measured. The relative abrasiveness of a given coal is determined by comparing the loss of weight of that disc against various other coal samples.

TABLE XI-4

Standard Materials on the Mohr Scale of Hardness (to the base 10)

1.	Talc
2.	Gypsum
3.	Calcspar
4.	Fluorspar
5.	Apatite
6.	Feldspar
7.	Quartz
8.	Topaz
9.	Sapphire
10.	Diamond

TABLE XI-5

Common Materials on the Mohr Scale of Hardness

Coal	0.5 - 2.5
Slate	0.5 - 6.0
Mica	2.0 - 6.0
Pyrite	6.0 - 6.5
Granite	6.5
Marble	3.0
Soapstone	1.0 - 4.0
Kaolin Clay	2.0 - 2.5
Beach Sand	6.5 - 7.0
Iron Ore	0.5 - 6.0
Window Glass	5.5 - 6.0
Carborundum	9.5
Thumb Nail	2.5
Copper Coin	3.0
Knife Blade	5.5
File	6.7
Emery	7.5

These tests generally corroborated the theory that the abrasiveness of coals varies according to the nature and amount of the extraneous impurities present in the sample, since the pure coal portions of the fuels examined had approximately the same low level of abrasiveness. The abrasive index cannot be used to rank coal since its impurities can combine in various ways to change the abrasive characteristic. As the quantity of shale present increases, the abrasiveness of the ash also increases considerably as shown in Figure XI-14. Figure XI-15 illustrates that there is a marked increase in abrasiveness with an increase in ash content. Tests with sink and float fractions at specific gravities of about 1.6 indicate that all float coals have the same low abrasiveness, which is below that of the initial coal. The sink fractions on the other hand, had a very high level of abrasiveness due to the high content of impurities. The results are illustrated in Figure XI-16 and XI-17.

Pyrite was also found to be extremely abrasive and an example of its abrasive index, when blended with coal, is illustrated in Figure XI-18. The presence of pyrite affects the abrasive characteristics in coal according to the quantity and size of pyrite particles disseminated throughout the coal. Hardgrove testing generally confirmed the quantitative effects of pyrite concentration on abrasive action and these are illustrated in Figure XI-19. Abrasiveness as related to pyrite particle size is indicated in Figure XI-20; there appears to be a critical size above which the abrasive index decreases rapidly with larger particle dimensions.

Haywood has further confirmed these findings by a series of tests run in an attempt to define the resistance of coals to grinding. The values cited in Table XI-6 demonstrate relative orders of magnitude; the procedures used are not as satisfactory as those of Parton, et al.

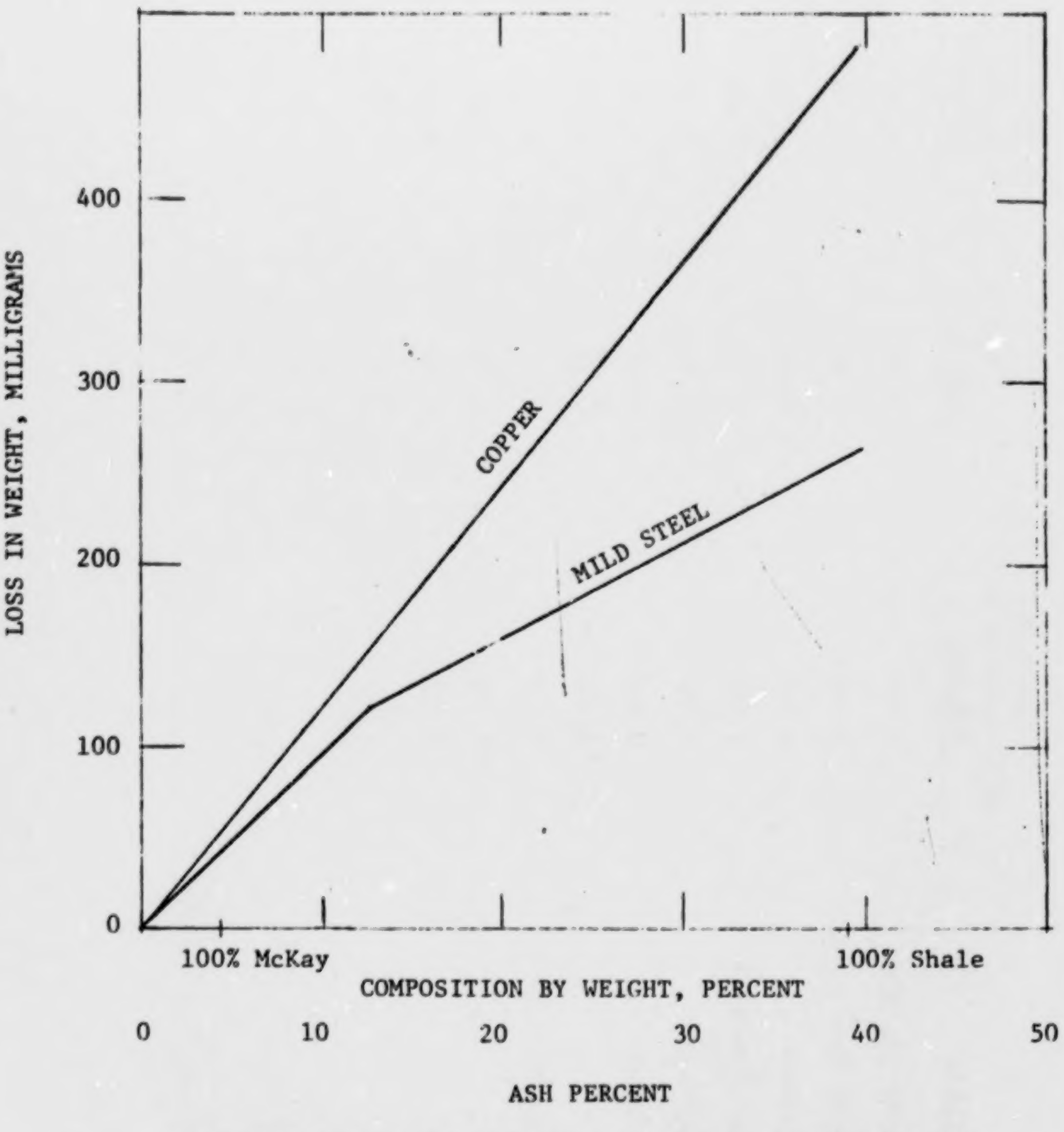
Parton, et al., indicate that the results of these experimental tests must be correlated with the actual instances of wear encountered in operations. However, the laboratory and field results cannot correspond since all of the wear on the industrial equipment is not due to the coal itself, but part is caused by direct metallic contact between parts of the equipment. Therefore, due to the absence of any substantial data, the results only provide a qualitative basis from which a judgment can be made in selecting a design.

TABLE XI-6

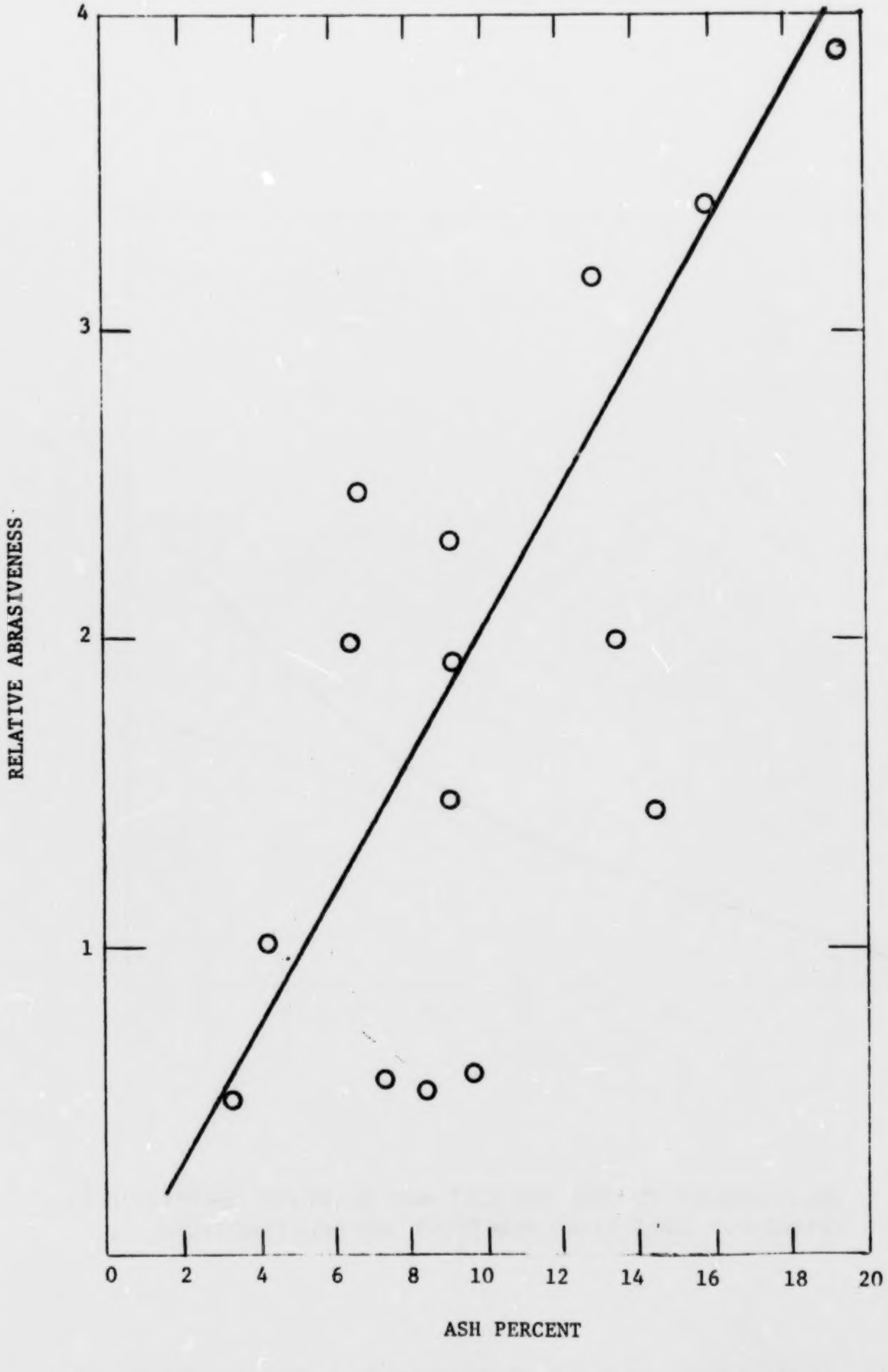
RESISTANCE TO GRINDING AND ABRASION EXPRESSED RELATIVELY TO THE VALUES FOR BARNSLEY SOFT COAL (20)

MATERIAL	CRUSHING ROLLS SURFACE ENERGY	ATTRITION TEST	SCRACTH HARDNESS TEST	ATTRITION TEST
Anthracite Gt. Mt.	1.09	5.33	1.70	2.35
Anthracite Red Vein	0.84	1.72	1.75	3.03
Welsh Steam	0.23	0.74	0.29	0.27
Barnsley Hards	1.09	1.11	0.85	1.24
Barnsley Softs	1.00	1.00	1.00	1.00
Illinois Coal	0.86	0.87	1.10	1.00
Cannel	1.32	2.52	0.92	2.71
Carbonaceous Shale	2.52	--	0.69	3.03
Shale	2.04	2.24	0.32	0.41
Pyrites	2.52	1.76	5.71	Ca 82.
Calcite	--	--	1.92	--

FIGURE XI - 14

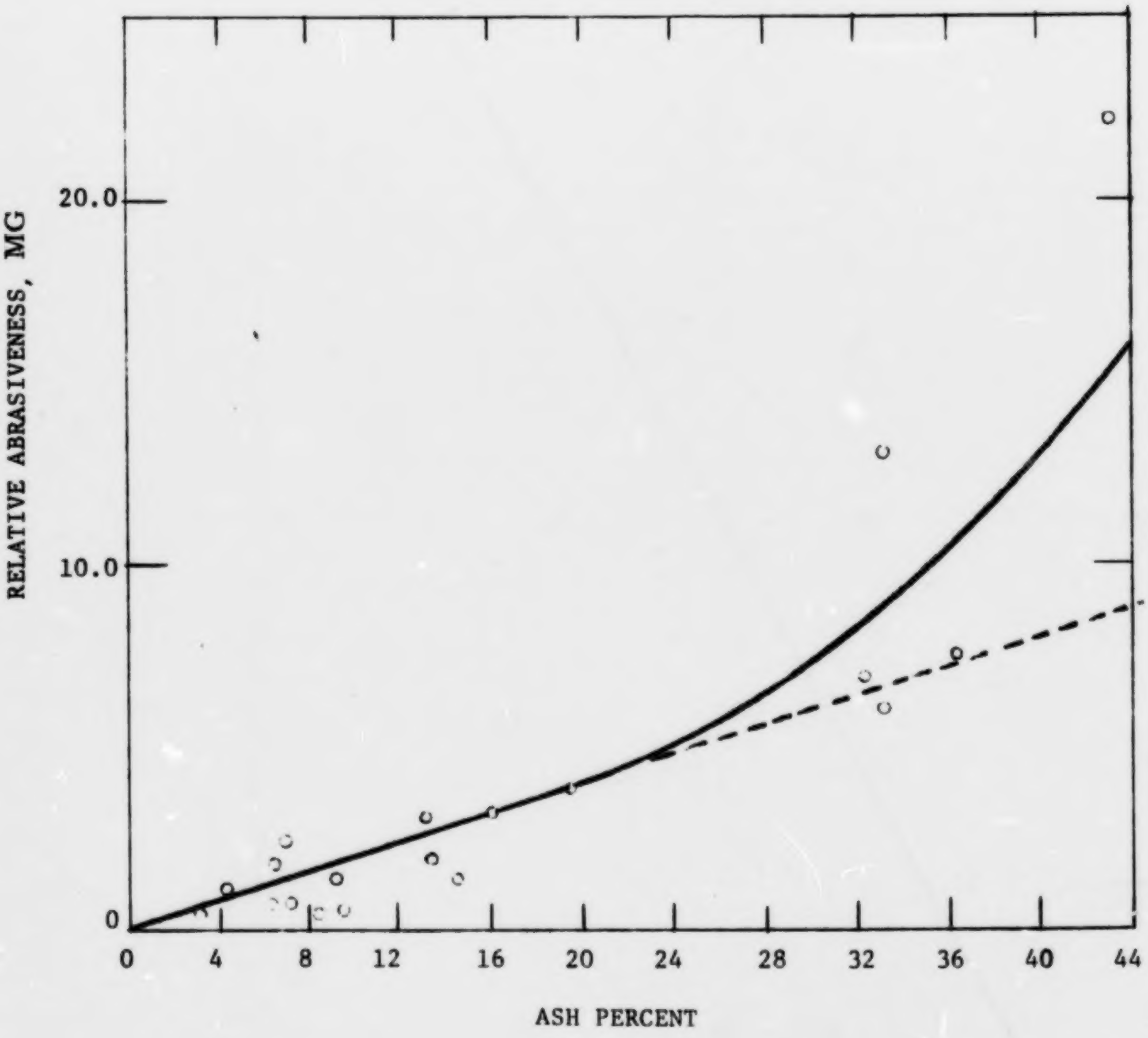


WEAR VS ASH CONTENT FOR THE McKAY-SHALE SERIES ON BOTH COPPER AND MILD-STEEL DISCS (14)



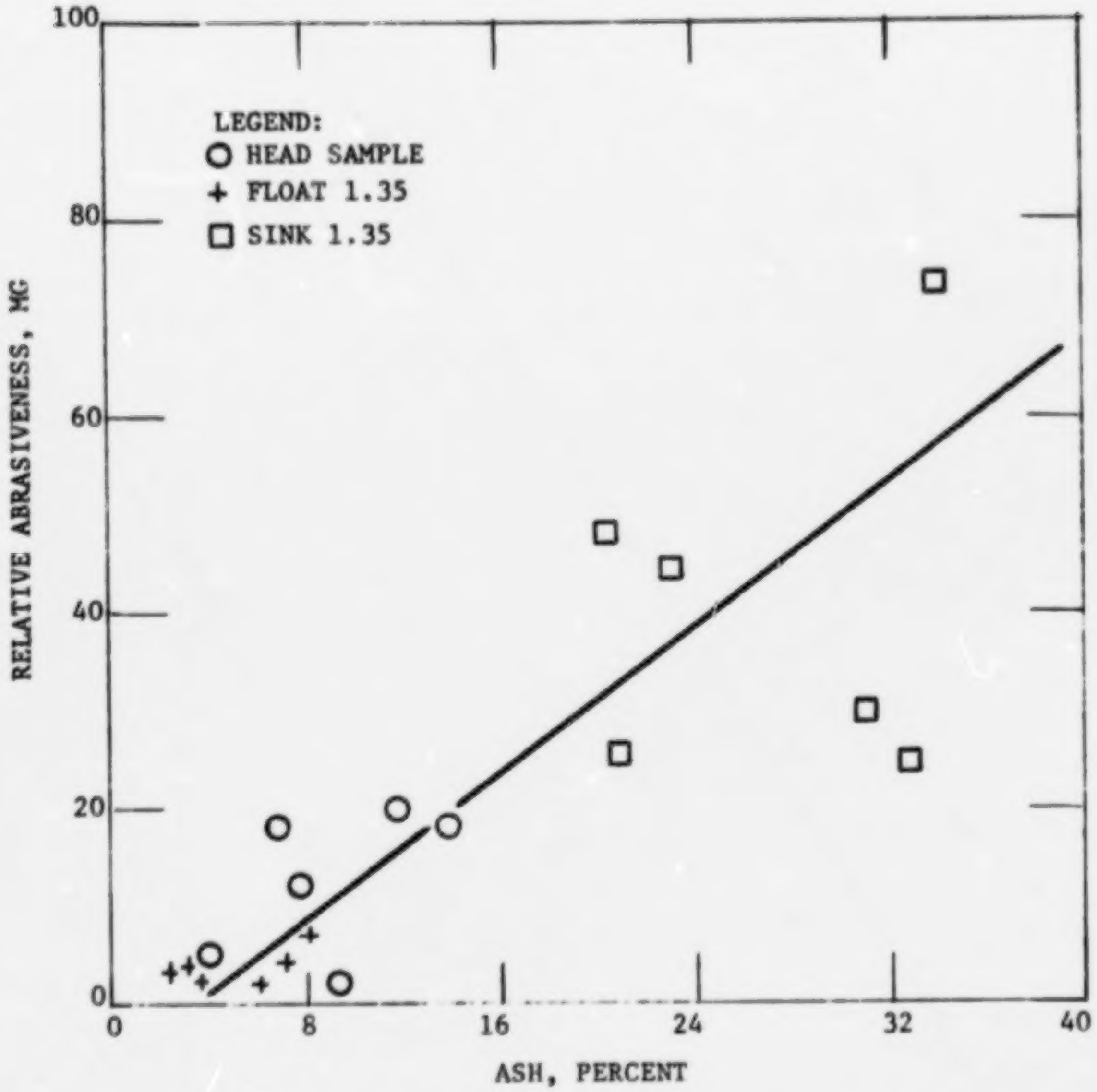
ASH CONTENT VS RELATIVE ABRASIVENESS FOR VARIOUS COALS (19)

FIGURE XI-16 -

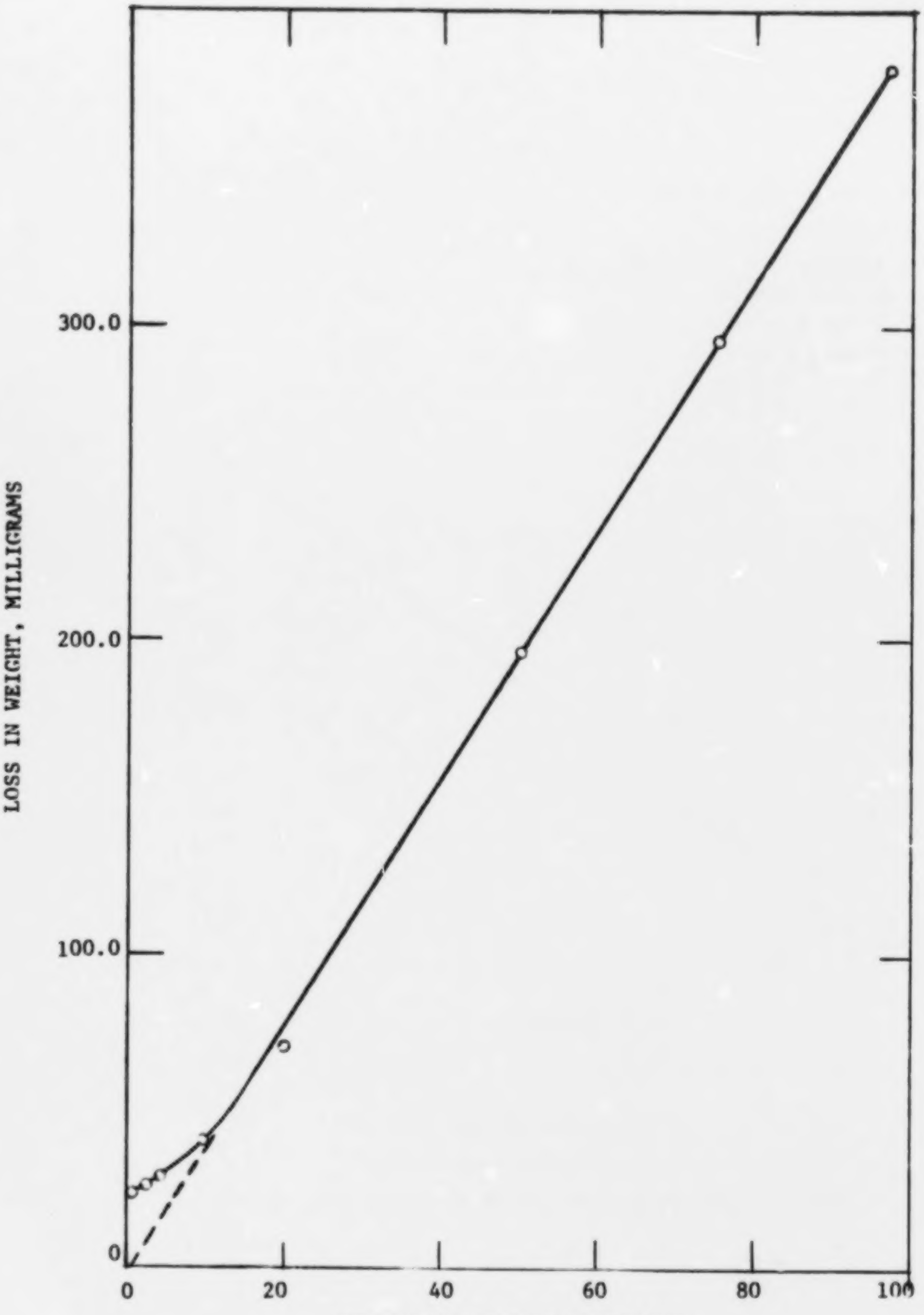


RELATIONSHIP OF ASH CONTENT AND RELATIVE ABRASIVENESS OF VARIOUS COALS, FLOAT FRACTIONS AND SINK FRACTIONS (19)

FIGURE XI-17-

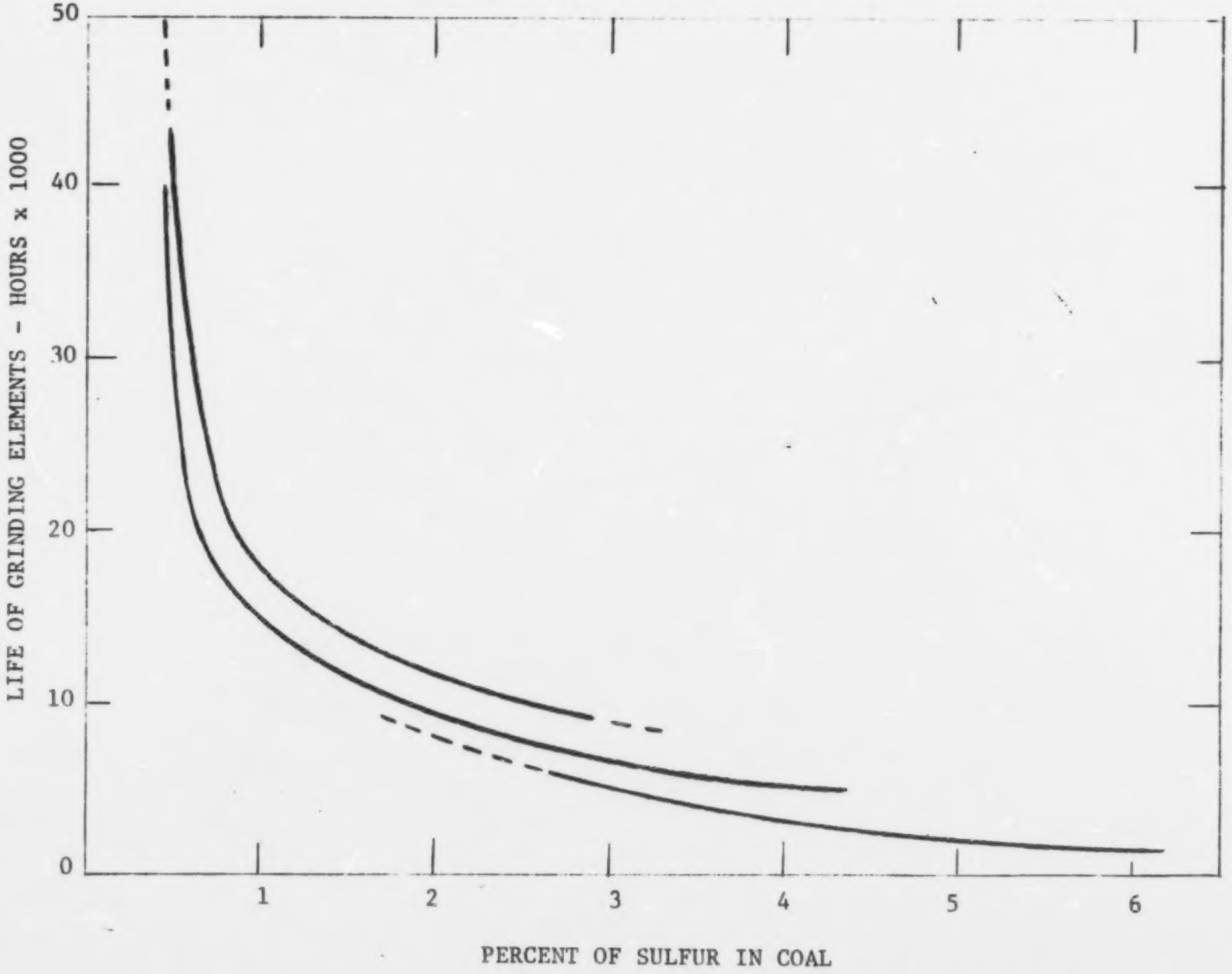


RELATIONSHIP OF ASH CONTENT AND RELATIVE ABRASIVENESS FOR VARIOUS COALS, FLOAT FRACTIONS, AND SINK FRACTIONS (20)

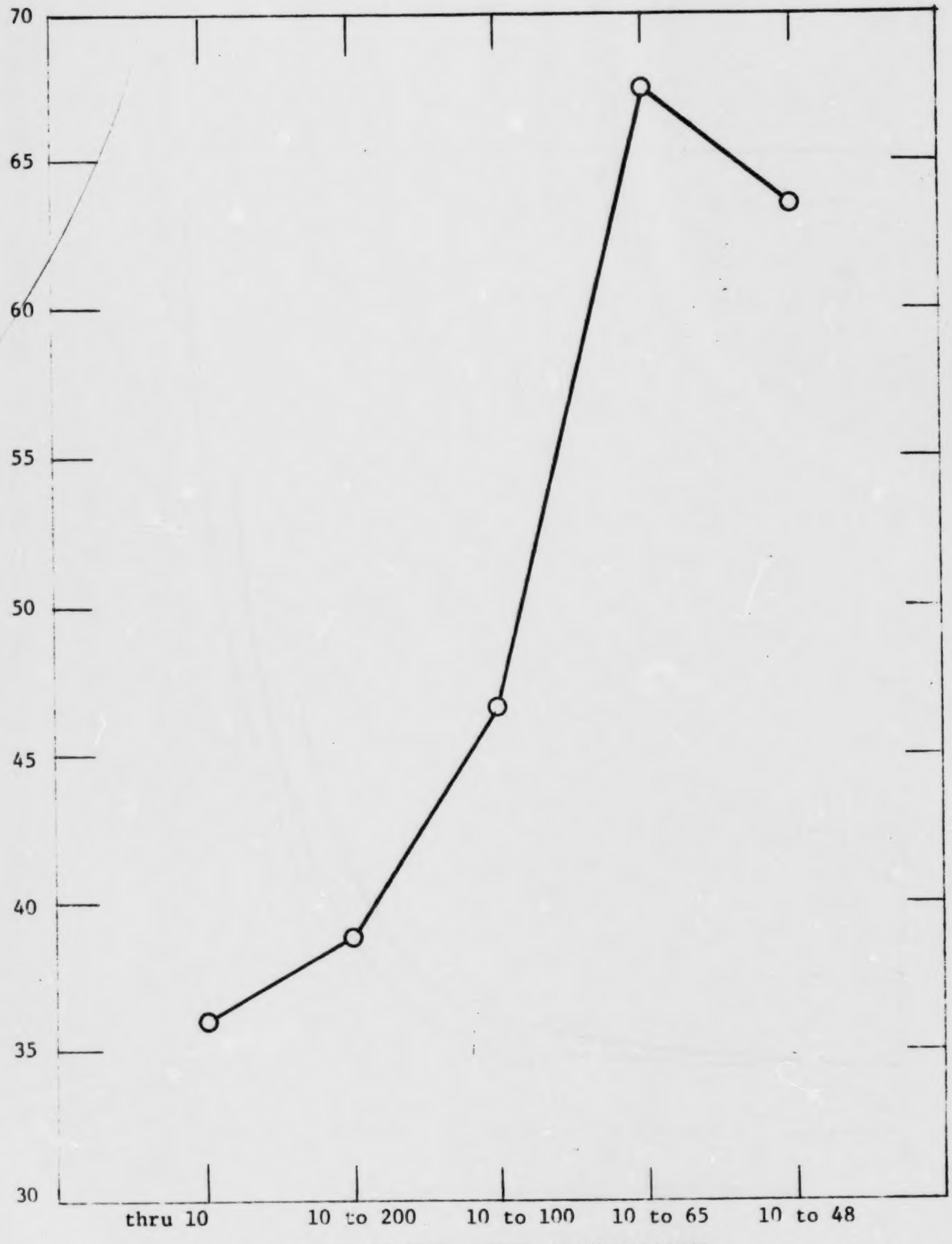


RELATIONSHIP OF WEAR AND PYRITE CONTENT
IN ROSLYN COAL (19)

FIGURE XI-19



EFFECT ON SULFUR (as FeS_2) IN COAL ON LIFE OF GRINDING ELEMENTS (19)



RELATIONSHIP OF ABRASIVE LOSS TO SIZE OF COAL (22)

4.2 Combustion Properties of HSC Fuels

4.2.1 Combustion Reactions

Iron pyrite (FeS+S) exists in many different crystal forms. The rhombic form of pyrite is called marcasite, has a specific gravity of 4.51, and is stable up to 750° F. The cubic form is the common pyrite having a specific gravity of 5.00 and is less reactive than marcasite. The elemental (labile) sulfur is released at low temperatures by the reaction:

$$FeS_2 + Q \longrightarrow FeS+S$$

In the absence of air or oxygen, the labile sulfur (23) in pyrite is released starting at 750° F, and at 1,470° F about 90% of it is liberated, leaving the residue pyrrhotite (FeS). Pyrrhotite can be roasted in the presence of air to form Fe_3O_4 and SO_2. This reaction starts at 760° F, while total desulfurization of the pyrrhotite occurs at 1,652° F. The reaction proceeds in the following manner:

$$3FeS + 5O_2 \longrightarrow Fe_3O_4 + SO_2 + Q$$

Likewise, in the absence of air or oxygen, pyrrhotite reacts with SO_2 to from Fe_30_4 and sulfur, according to the following:

$$3FeS + 2SO_2 \longrightarrow Fe_30_4 + 5S \quad \text{(Reference 24)}$$

According to the phase diagram for the iron-sulfur system, sulfur and oxidized iron form low melting constituents as a result of the distillation of sulfur and its resulting reaction with iron ahead of the flame front or combustion zones (25). This situation causes the iron ore to agglomerate and impedes further combustion. Also, according to Dr. Biswas (26), the combustion of iron ore in flash roasting is impeded by the formation of a melt containing the larger particles and inhibiting the subsequent distillation of sulfur. This phenomenon yields a substance similar to the casing found on carbon particles during the combustion of pulverized coking coals, and is more appropriately considered in detail under combustor design.

These phenomena are exploited in the process of Outokumpu Oy as follows: Pyrite is heated by oil burner, under stoichimetric or slightly reducing conditions; (the combustion gases must be oxygen free to avoid converting the sulfur to sulfur dioxide). Sulfur is formed and carried off in the flue gases. The reaction time is about 1.5 seconds. The pyrrhotite is collected in a molten phase, then withdrawn, quenched, and roasted in the presence of oxygen to form iron oxide and sulfur dioxide.

Accordingly, FeS_2 can be considered as having a similar combustion chemistry to conventional fuels although a lower heating value; it is not a chemically inert material as might otherwise be expected due to its nature as a non-carbonaceous mineral found in coal. Also it has been shown that pyrite contains a large percentage of volatile matter which is released at relatively low temperatures, giving it good ignition characteristics as a fuel. Reasonably high flame temperatures should be achieved as well since less air per pound of fuel is required than for coals. Although incomplete combustion may occur due to the more stable phase of pyrrhotite formed during combustion together with an intermediate molten phase, proper pretreatment of the fuel and distribution of excess air can counteract these effects.

In order to understand fully the implications of firing such an unusual fuel in terms of furnace design, the whole combustion process must be broken down into two distinct phases, namely, ignition and the burnout. The first was formerly evaluated in terms of fuel ignitability and volatility, but recently, the reactivity index has also been used as a more accurate and reliable reference. The second phase is usually considered in terms of total energy of activation or burning rates achieved. Each index is discussed below both for pyrite and for blends of pyrite, coal, and ash, as well. Tests were run to determine the actual values for various blends.

4.2.2 Volatility

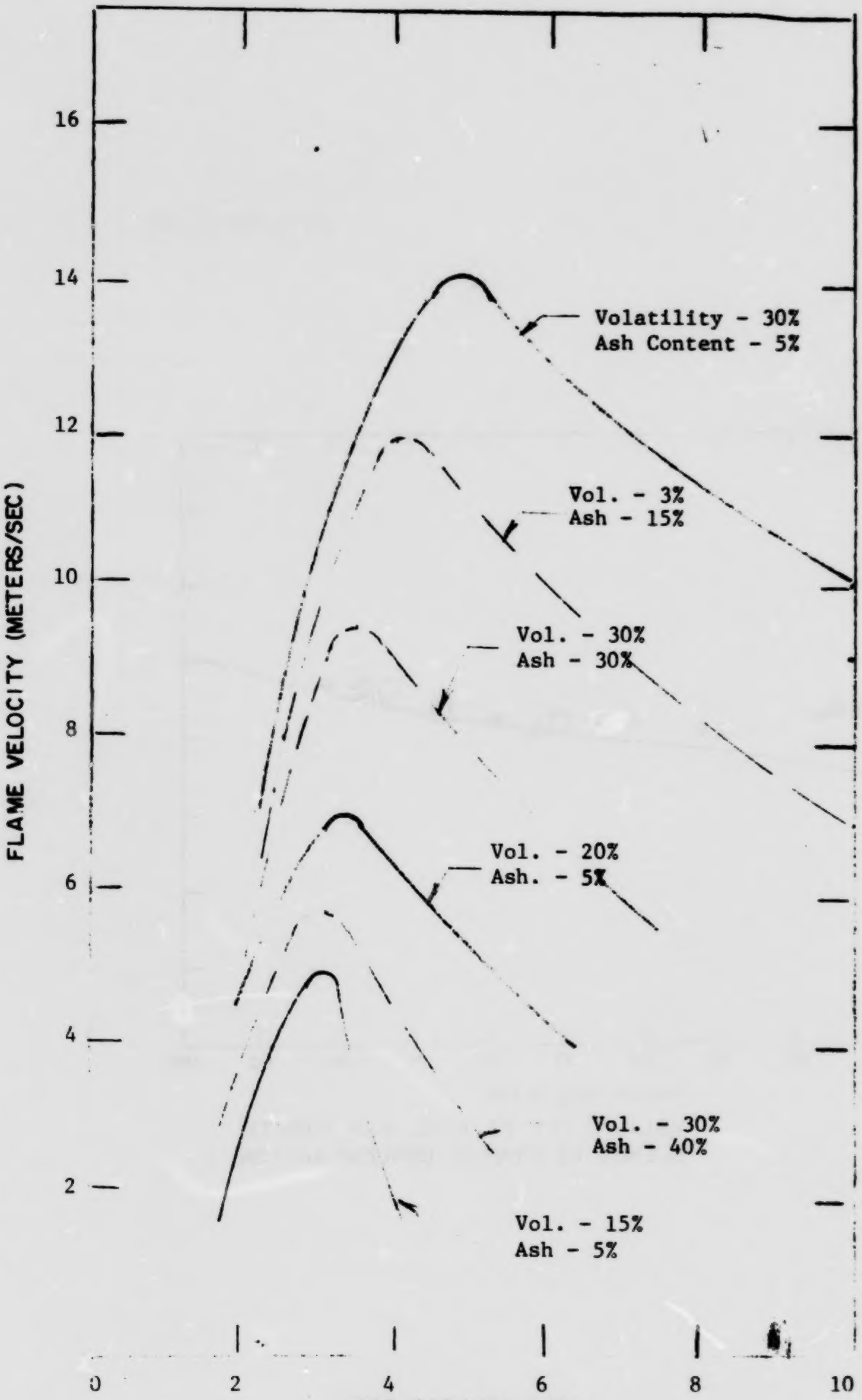
Pure coal is empirically divided between volatile matter and fixed carbon as follows: that portion which is liberated as vapor by heating to 950° C for seven minutes is defined as volatile matter; the remainder being fixed carbon. In the case of ordinary coals, volatile matter would include water vapor, carbon dioxide, combustible gases, (mainly hydrocarbons), and small quantities of phenolic and other compounds (10). When coal is blended with pyrites, the volatile matter also includes labile sulfur. The volatile matter of the fuel furnishes ready heat since it ignites at lower temperatures and increases the rate of combustion.

Volatility also measures the rate of combustion, particularly during the early stages. Figure XI-21 illustrates the effects of volatility on flame velocity, and the speed with which the fuel must be fired to avoid transmitting the flame beyond the confines of the furnace. With the highly volatile fuels, more air is needed during the early stages of combustion, because greater turbulence is produced and shorter flames are encountered.

The volatilities of various blends of pyrites and Pocahontas No. 3 coal were determined in laboratory tests, and the results are shown in Figure XI-22. A higher initial value than expected in volatility occurred at first, probably due to a slight anomaly in the coal. The subsequent increase is not significant in the range of 20-70% pyrites, but above 80%, the volatility improves at a slightly faster rate. This tendency indicates that the decrease in volatile matter content in coal is more than offset by the increase in labile sulfur in the pyrites. Based on the consideration of volatility alone, blends of pyrites and coal have better ignition and combustion characteristics than pure coal.

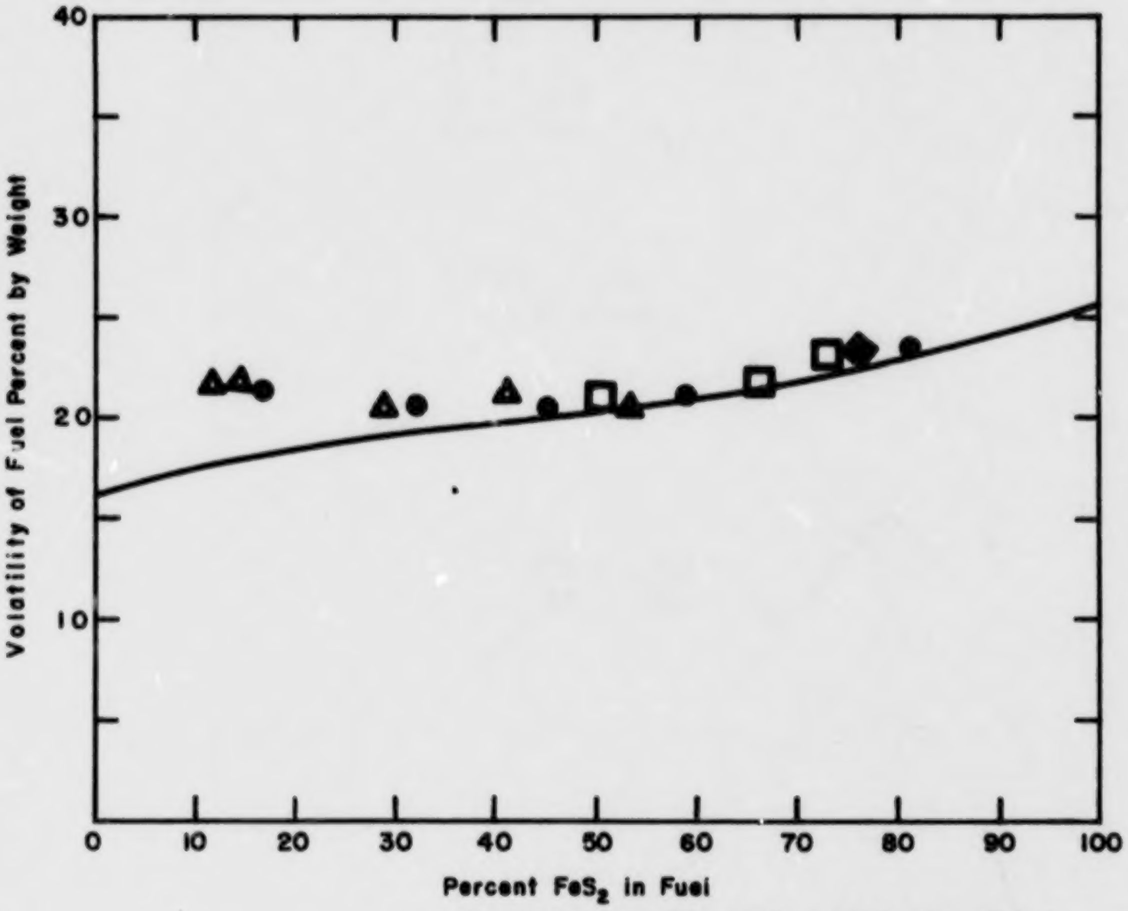
4.2.3 Ignitability

Ignition tests consist of passing a coal sample pulverized to a 44 micron #325 sieve size into the vertical tube of an electric furnace, and increasing the furnace temperature until a small flash or glow signifies that the ignition temperature has been



EFFECT OF VOLATILITY OF COAL ON FLAME VELOCITY
FOR VARIOUS AIR/FUEL RATIOS AND ASH CONTENT

FIGURE XI-22



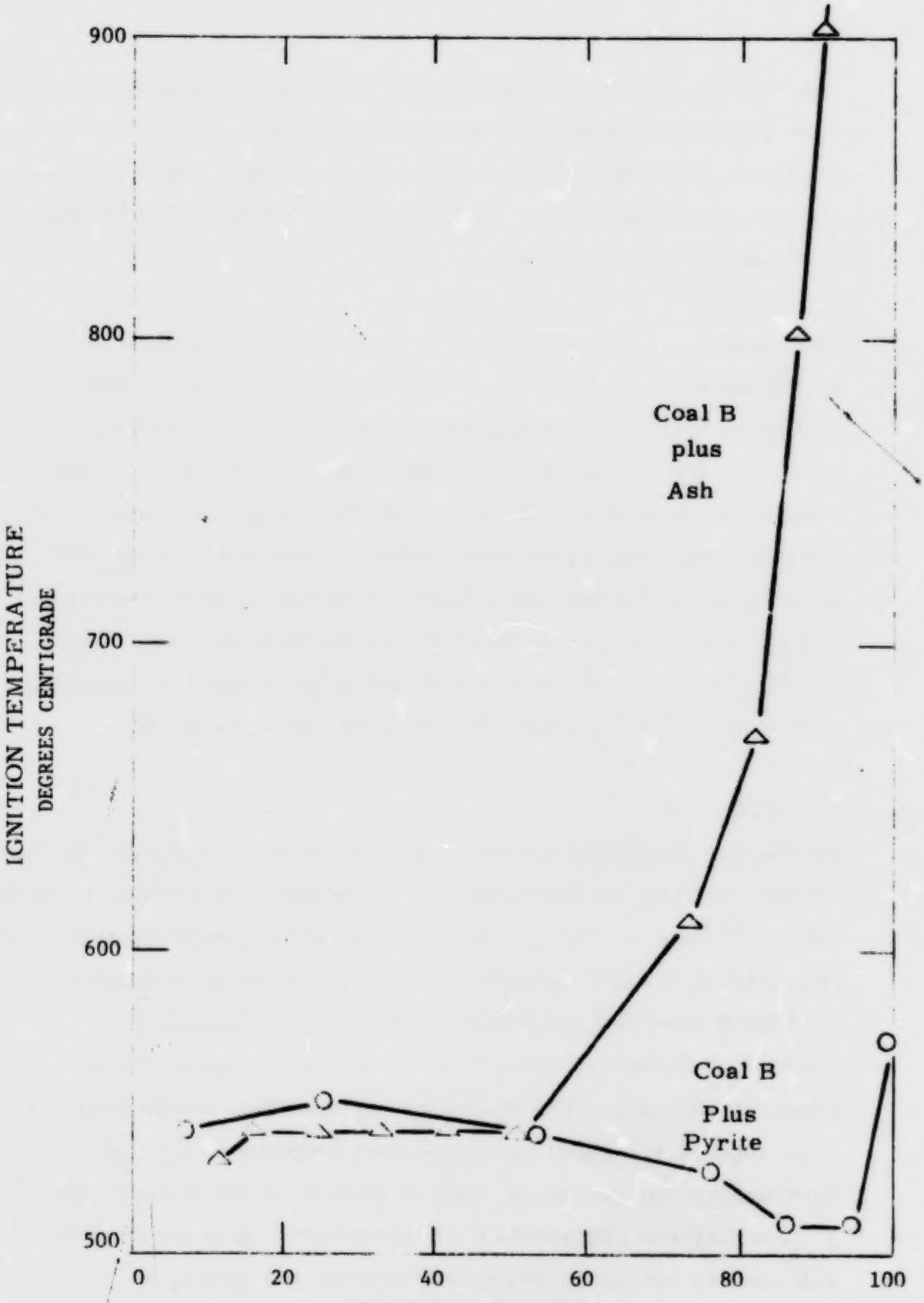
VOLATILITY OF COAL, ASH, PYRITE BLENDS VS PYRITE CONCENTRATION reached. The ignition temperatures reported for various fuels have generally followed the correlation in Figure XI-23, relating ignitability and volatile matter content. Also, these ignition temperatures have frequently predicted the ignitability of a fuel in the actual field installations.

For example, Liddel and Down (9) report that the ignition of pyrite takes place at 618° F, according to particle size; Borio and Spicer (17), investigating the effects of inerts as well as pyrites on the ignition point of coal, found that the ignition was suppressed when the inerts level exceeded 60%, i.e., that ignition temperature increased rapidly. However, the ignition point of pyrites is low, well below the values cited for the coal sample with which it was blended, and the data shown in Figure XI-23 indicate that there was a steady improvement in ignitability with an increase in pyrite concentration, up to about 95%.

4.2.4 Reactivity

Neither the proximate analysis, nor the ultimate analysis, nor the ignition test has been completely satisfactory in predicting combustion performance. To fill this void of quantitative background, the reactivity test was developed; this test grew out of work done at the Coal Research Laboratory of the Carnegie Institue of Technology by Sebastian and Mayers (27) on the ignition and reactivity of coals. The reactivity, unlike other combustion tests, appears to reflect an independent property of the fuel. Specifically, the reactivity index is defined as the temperature, T_{15}, in degrees centigrade (° C), corresponding to an adiabatic self-heating rate of 15 centigrade degrees per minute in

FIGURE XI-23



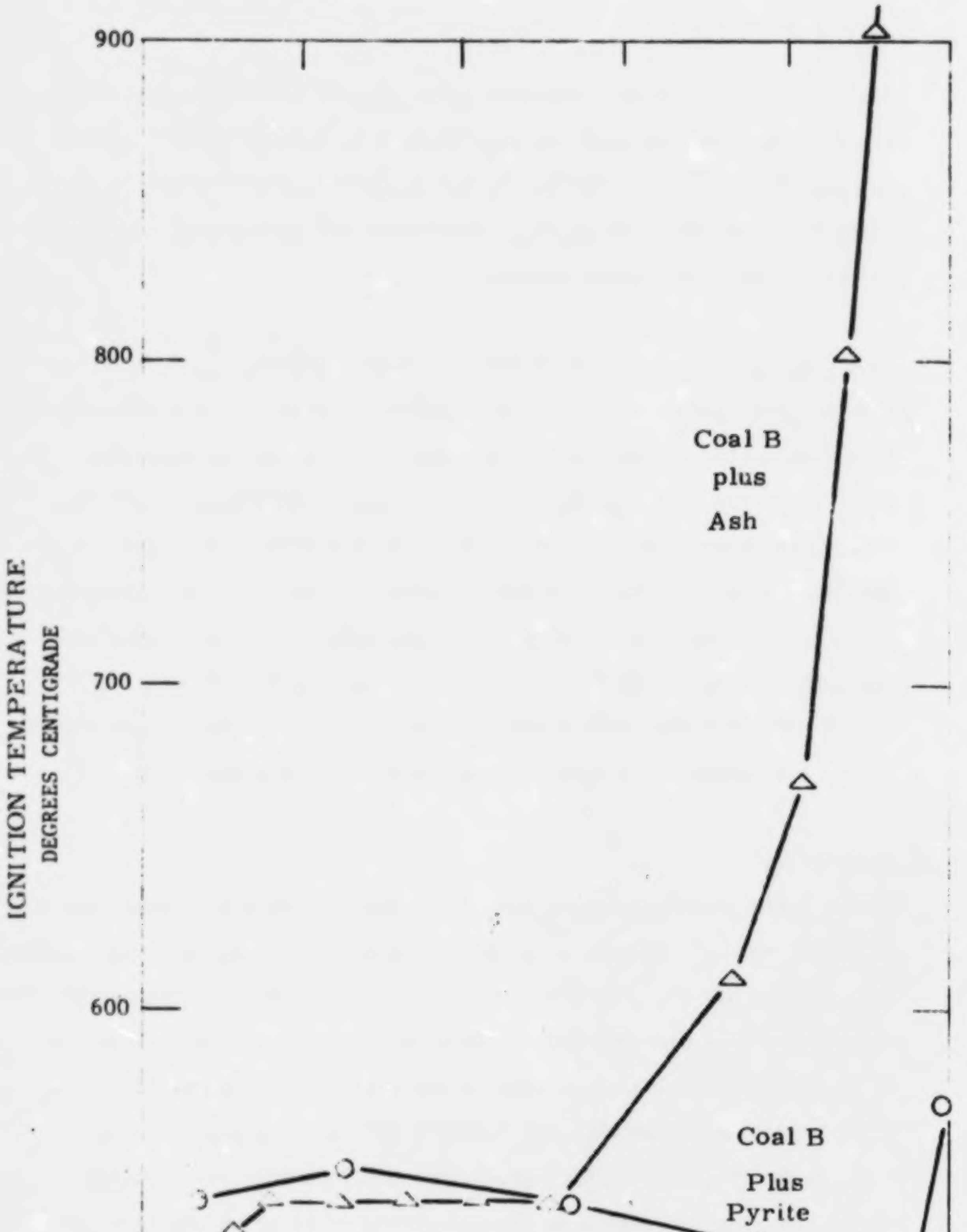
IGNITION TEMPERATURE VS. PYRITE OR ASH (17) reached. The ignition temperatures reported for various fuels have generally followed the correlation in Figure XI-23, relating ignitability and volatile matter content. Also, these ignition temperatures have frequently predicted the ignitability of a fuel in the actual field installations.

For example, Liddel and Down (9) report that the ignition of pyrite takes place at 618° F, according to particle size; Borio and Spicer(17), investigating the effects of inerts as well as pyrites on the ignition point of coal, found that the ignition was suppressed when the inerts level exceeded 60%, i.e., that ignition temperature increased rapidly. However, the ignition point of pyrites is low, well below the values cited for the coal sample with which it was blended, and the data shown in Figure XI-23 indicate that there was a steady improvement in ignitability with an increase in pyrite concentration, up to about 95%.

4.2.4 Reactivity

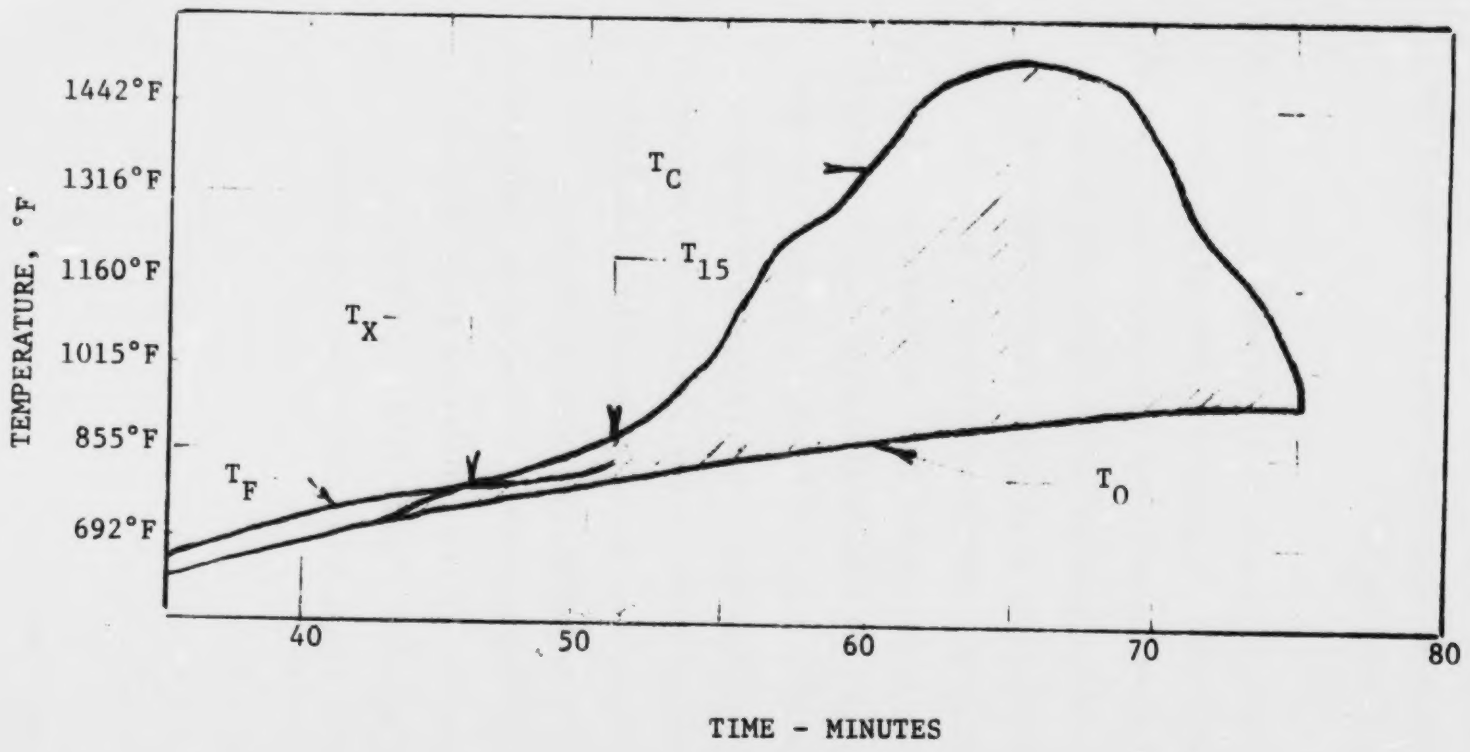
Neither the proximate analysis, nor the ultimate analysis, nor the ignition test has been completely satisfactory in predicting combustion performance. To fill this void of quantitative background, the reactivity test was developed; this test grew out of work done at the Coal Research Laboratory of the Carnegie Institue of Technology by Sebastian and Mayers (27) on the ignition and reactivity of coals. The reactivity, unlike other combustion tests,appears to reflect an independent property of the fuel. Specifically, the reactivity index is defined as the temperature, T_{15}, in degrees centigrade (° C), corresponding to an adiabatic self-heating rate of 15 centigrade degrees per minute in

FIGURE XI-23



IGNITION TEMPERATURE VS. PYRITE OR ASH (17) pure oxygen. Figure XI-24 illustrates the T_{15} temperature index performed by Long and Wheeler (28) on a Pocahontas No. 3 coal. It reflects the low temperature-oxidation characteristic of the fuel and is closely related to ignitability. As in the case of ignition temperature, the higher reactivity index corresponds to a less reactive or less ignitable fuel.

The reactivity test is performed in a C.R.L. reactivity furnace such as that sketched in Figure XI-25. A sample of fuel of standard weight and size is placed on the grid in the reaction tube. Two of these tubes are used in a determination of the reactivity index. In one tube, a standard flow of air is passed, and through the other, a standard flow of oxygen. The temperature of both the samples and the furnace increase as the heat is liberated. The fuel, as it oxidizes, produces its own heat energy and increases in temperature at a faster rate than the furnace. There are then two points at which the temperatures of the sample are equal to the furnace: at initial conditions and at equilibrium, the two times at which there is no heat flow to or from the sample. Between these conditions, the rate of temperature rise becomes a measure of the reactivity of the sample. By using the different oxidizing gases, it is possible to obtain different rates of rise of various sample temperatures. These rates are then correlated by the Arrhenius equation in the manner described in Part IX-6.3.



CHARACTERISTIC TIME-TEMPERATURE CURVE FOR POCAHONTAS NO. 3 COAL

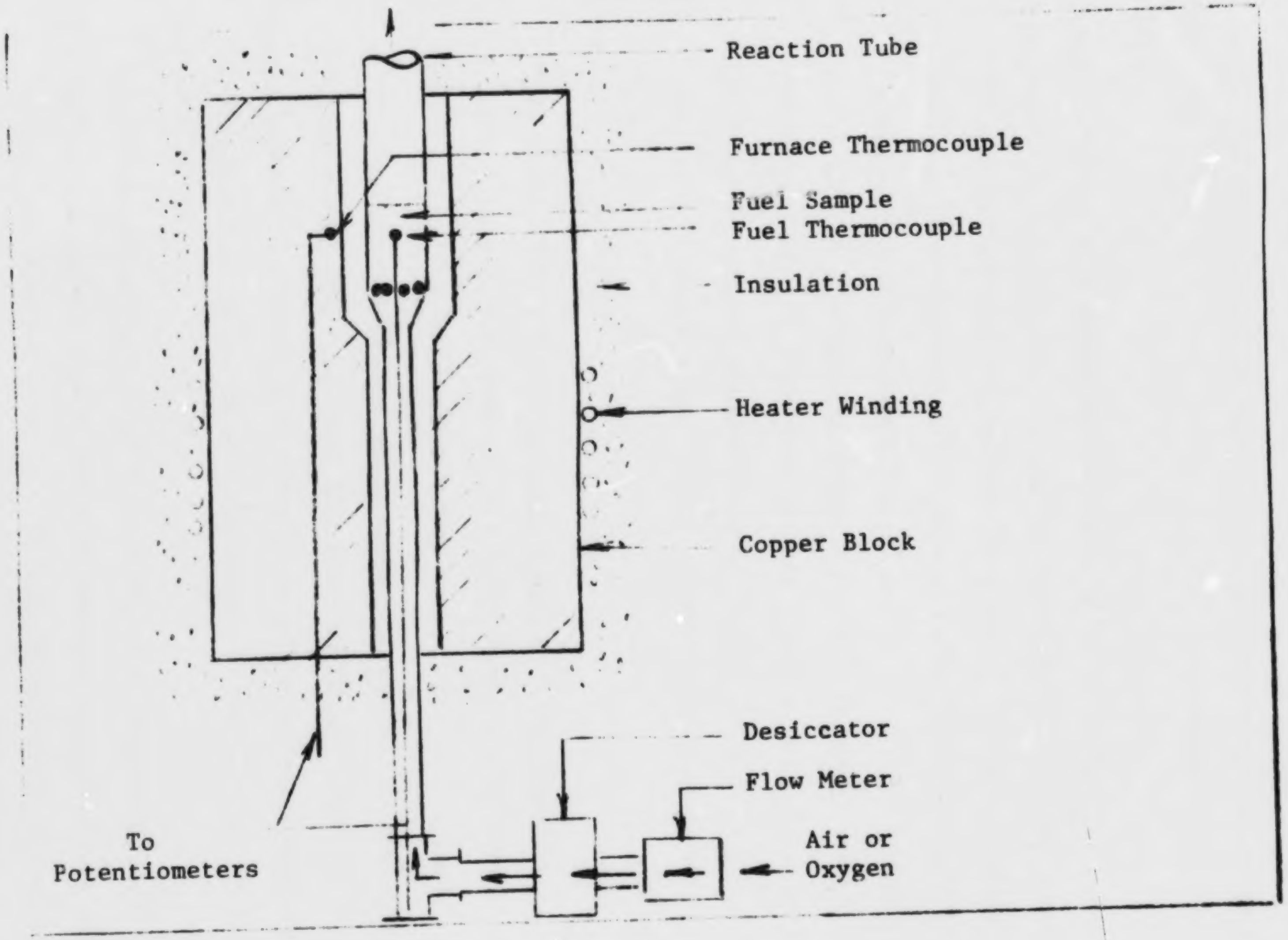
T_X = Standard Ignition Temperature
T_{15} = Reactivity Temperature
T_F = Furnace Temperature
T_C = Temperature of Coal
T_0 = Calibration Curve - Temperature of Holder without Coal

FIGURE XI-24

FIGURE XI-25

APPARATUS FOR DETERMINING CRL

REACTIVITY INDEX OF SOLID FUELS


Reaction Tube
Furnace Thermocouple
Fuel Sample
Fuel Thermocouple
Insulation
Heater Winding
Copper Block
Desiccator
Flow Meter
Air or Oxygen
To Potentiometers

SCHEMATIC DIAGRAM OF A CARNEGIE RESEARCH LAB. REACTIVITY FURNACE

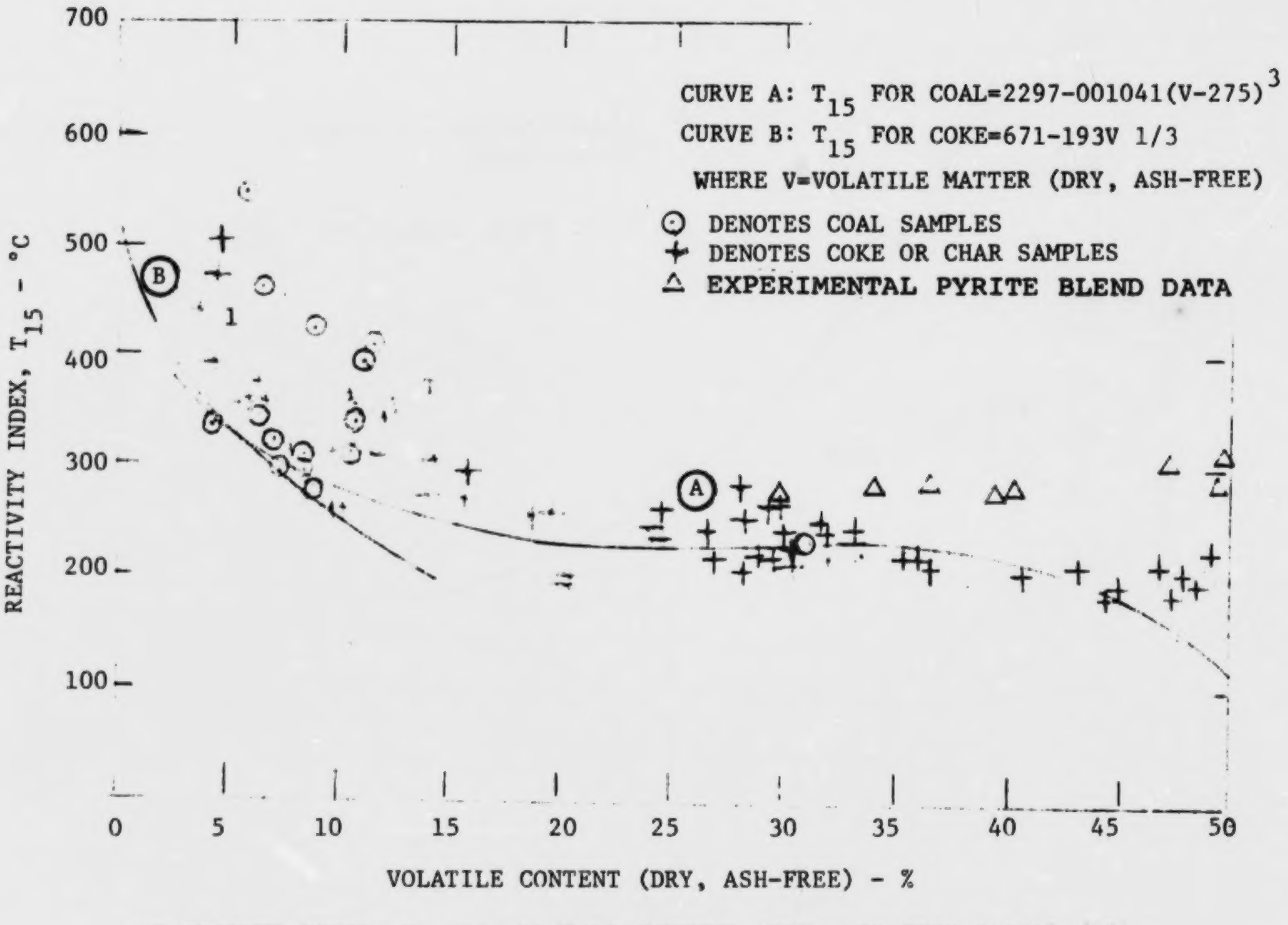
From this equation the reactivity index T_{15} is defined as the temperature at which the rate of rise in pure oxygen would be 15C° per minute.

As a verification of the generally held belief that ignitability can be correlated closely with the volatile constituents of solid fuels, samples were run in the Foster Wheeler Laboratory and the Carnegie Institute of Technology (29), and the results are shown in Figure VI-26. The Carnegie Laboratory also developed formulae shown as Curves A and B in this figure. Ceely and Wheater (29) found many values differed from the computed values by 75-200C° also shown in Figure XI-26. Most of the samples were foreign fuels, though some were of American origin.

As a case in point, consider samples No. 1 and 2: Sample No. 1 is a readily burnable Pennsylvania anthracite coal, while sample No. 2 is practically unignitable meta-anthracite from Rhode Island. An examination of the proximate analysis of these samples would indicate that they have similar combustion characterisitics and are each difficult to burn. However, actual tests revealed a far different picture as shown in the figure.

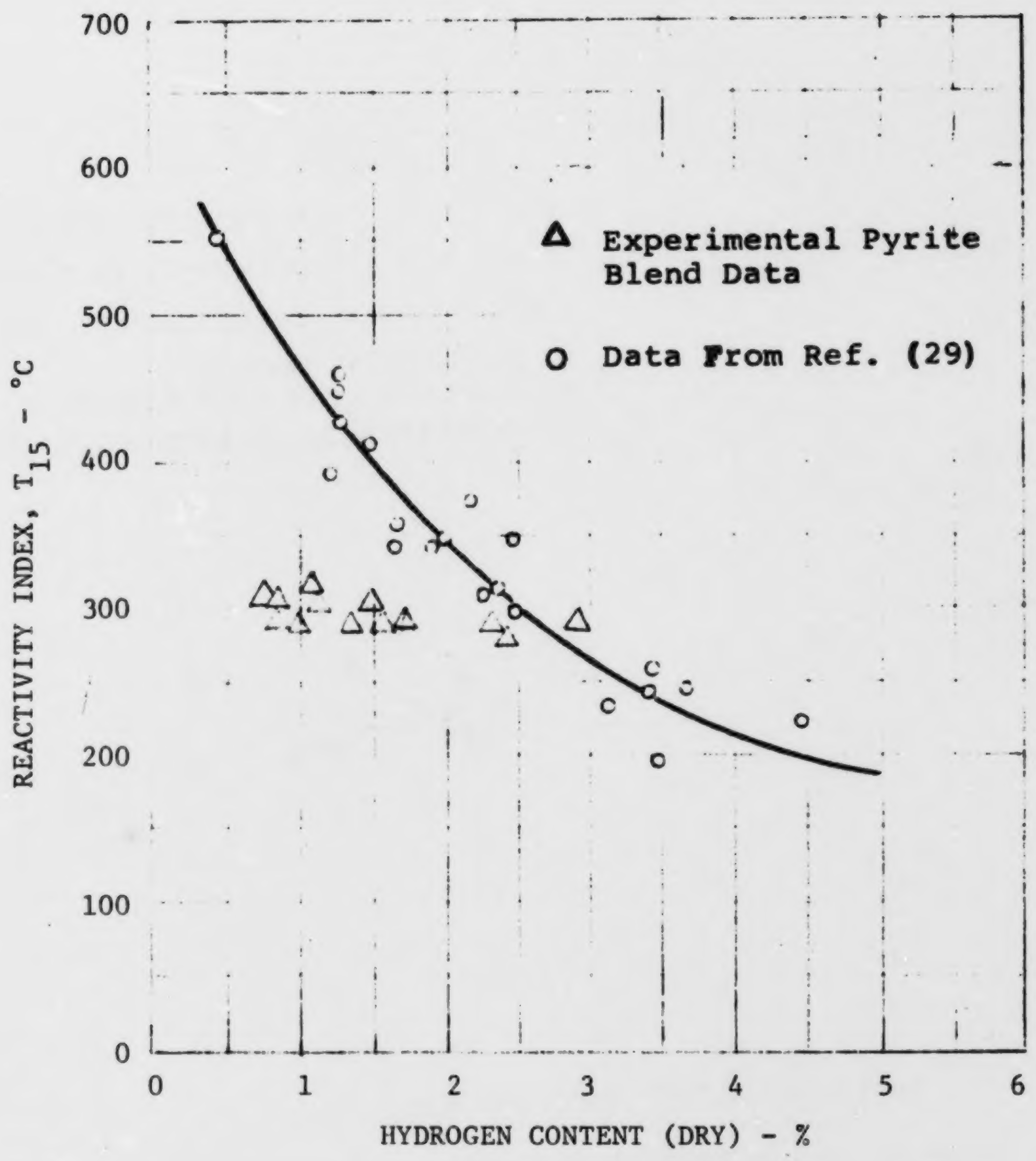
Further, attempts have been made to correlate the reactivity index and hydrogen content on a dry weight basis, and these results are shown in Figure XI-27. It is evident that some relationship exists, but the maximum deviation from the curve is about 45C°. Figure XI-28 shows the same relative significance on a dry, ash-free basis, and the temperature deviation

FIGURE XI-26



REACTIVITY INDEX T_{15} vs VOLATILE CONTENT (DRY, ASH-FREE BASIS) (29)

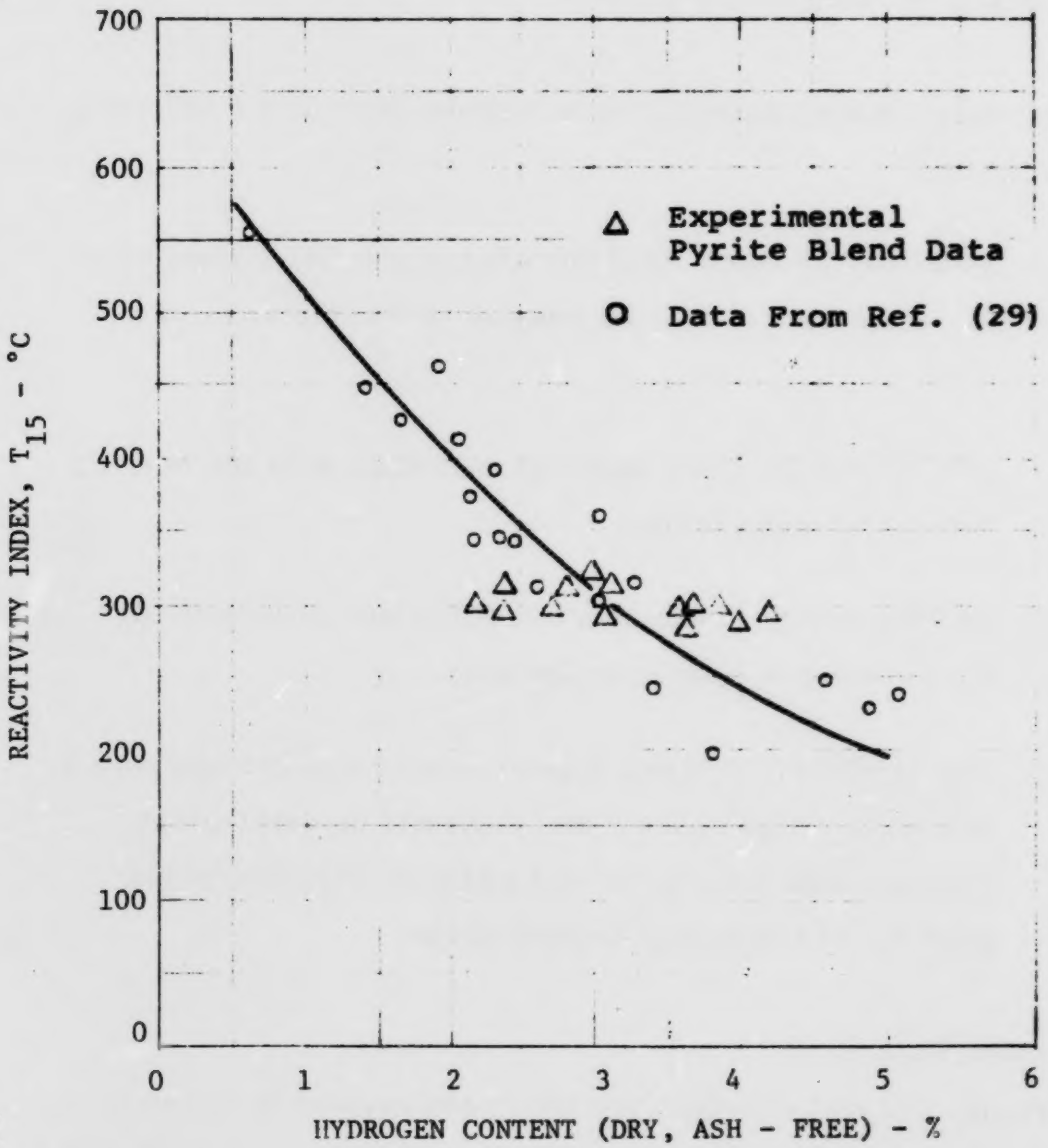
FIGURE XI-27-



REACTIVITY INDEX T_{15} VERSUS HYDROGEN CONTENT:

DRY BASIS (29)

FIGURE XI-28



REACTIVITY INDEX T_{15} VERSUS HYDROGEN CONTENT: DRY, ASH-FREE BASIS (29) is even greater than this. In either case, the deviation from predicted values is too large to consider this correlation as a satisfactory quantitative guide.

Therefore, these empirical observations lead to the following conclusions:

1) Volatility by itself does not always provide a good index for evaluation of the combustion characteristics of a fuel.

2) The reactivity index does not correlate with the volatile content of many fuels.

3) The reactivity index does not correlate satisfactorily on the basis of hydrogen content.

4) The reactivity index is a good measure of the ignitability of a wide range of fuels and it should be determined together with proximate and ultimate analysis in the process of evaluating unusual fuels.

4.2.5 Burning Rate

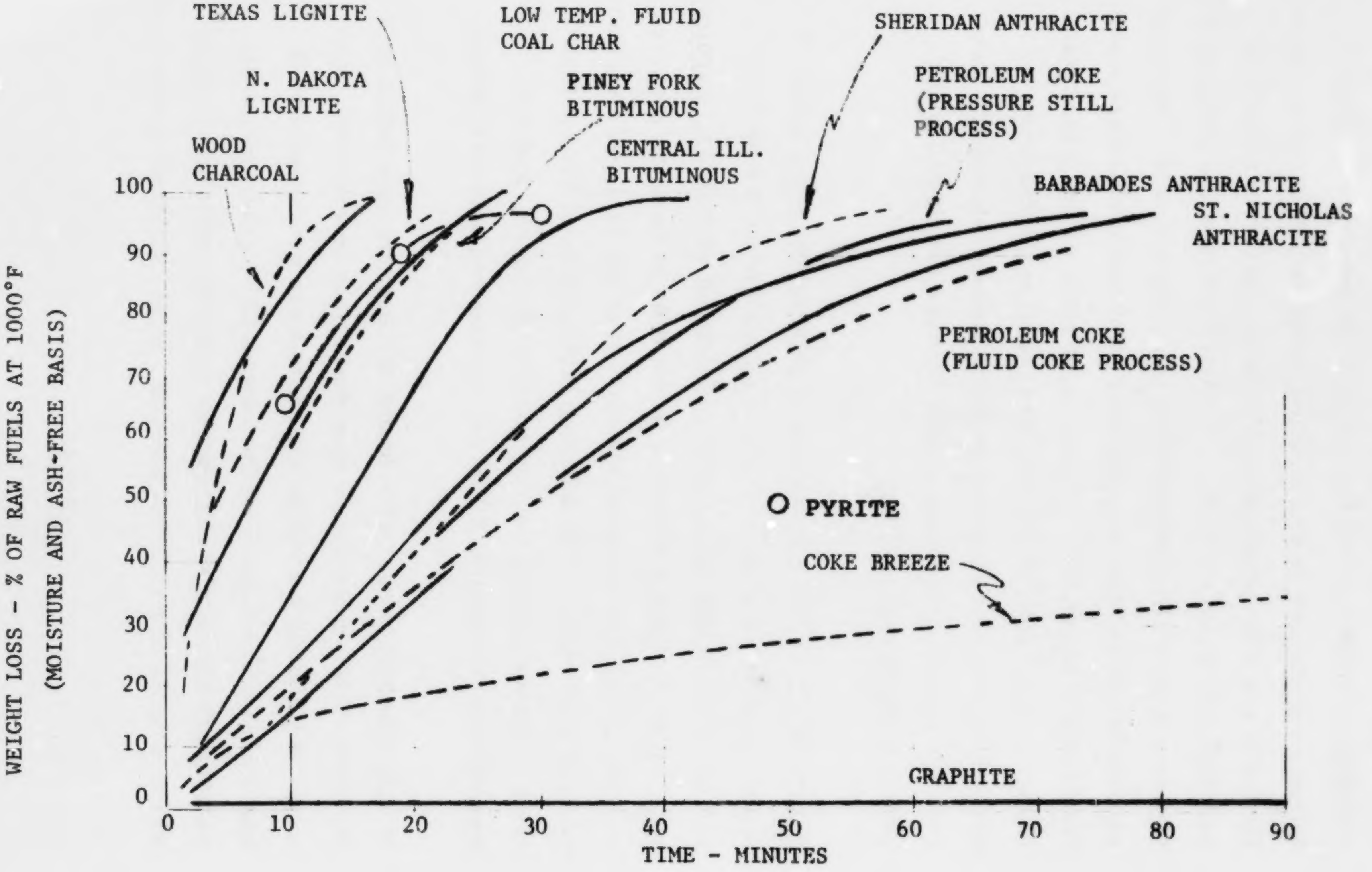
Burning rate test results have long been studied in order to evaluate more fully the effect of the second phase of combustion on the burnout phase, and to eventually predict the percent burnout expected at a given temperature for a given percent oxygen in a specified residence time.

Oshima (30) proposed a method employing a programmed furnace for the thermogravimetric analysis of a coal sample. The data generated were used to determine the combustion rate or burnout index. This method performs a continuous weighing of a coal sample during combustion in a furnace maintained at a controlled temperature under a constant flow of air to the combustion chamber. Since the sample is suspended in a pan, with the air entering below the sample, the process is partially controlled by the diffusion rate. Tests at several temperatures indicate that combustion rates are also temperature dependent. The burning rates of the fuels established by this test, of course, are not of the same order of magnitude as those expected in the furnaces. However, their relative values under comparable furnace conditions would probably be the same (11).

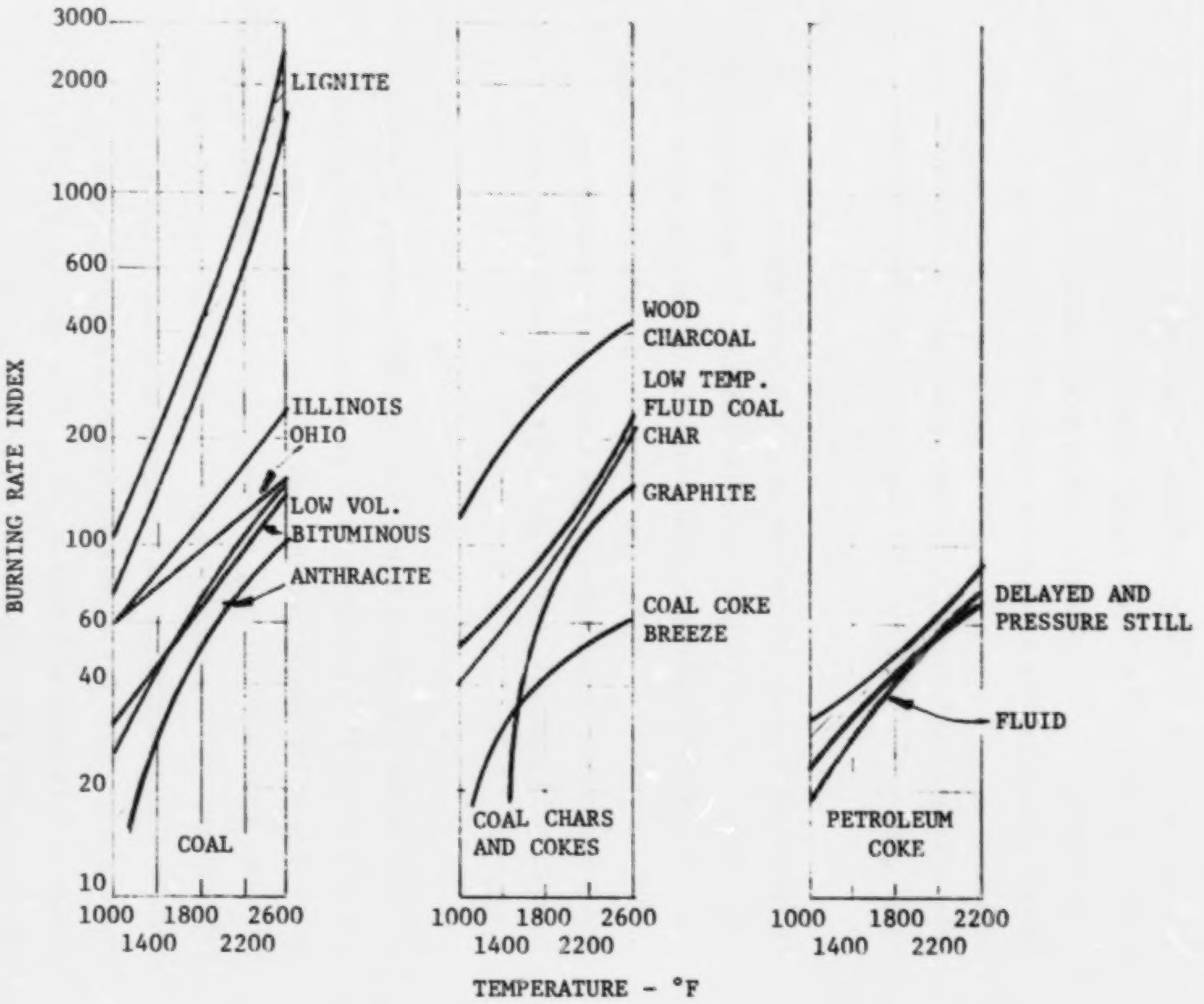
Figure XI-29 shows typical weight loss curves for a range of fuels. A burning rate index is calculated from the moisture and ash free weight loss curve and defined as follows: burning rate index = 1000/T where T is the time in minutes required to burn 80% of the combustible content of the fuel, on a moisture and ash free basis. The burning rate indices of the various fuels are used mainly for comparison purposes, and are summarized in Figure XI-30 for various temperature levels.

It would be highly desirable to use the burning rate index as a measure of the unburned carbon that might be expected; however, in defining the index, the tests were conducted on the basis of 80% combustion of the carbon (20% unburned carbon remaining) and do not correspond to actual operating conditions where a level of 1 to 2% is desired. Also, at these levels, the

FIGURE XI-29



LOW TEMPERATURE BURNING RATES FOR A RANGE OF FUELS (11)



BURNING RATE INDICES FOR A RANGE OF FUELS TESTED IN AIR (11)

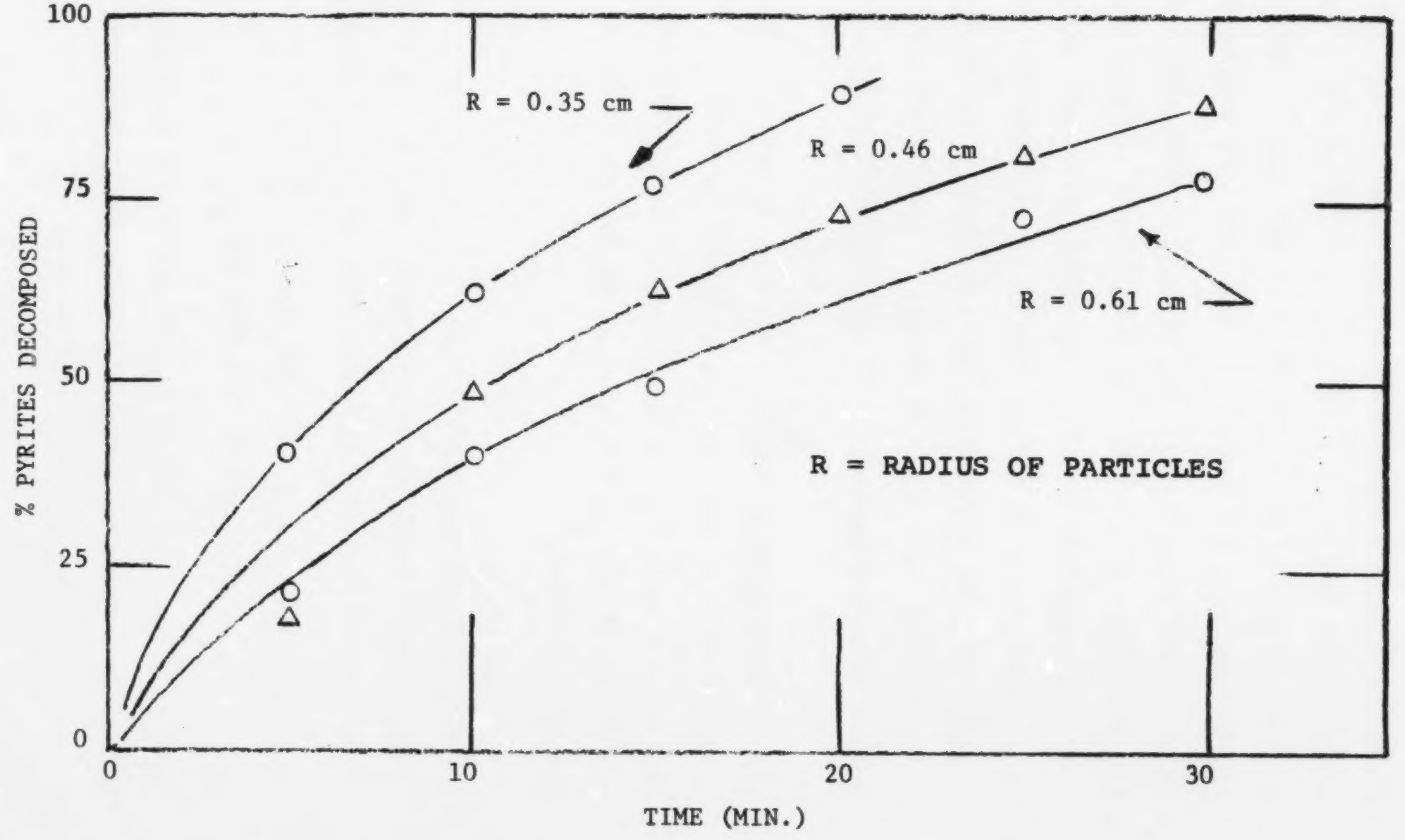
FIGURE XI-30

rate of combustion drops off rapidly in an exponential manner and extrapolation becomes impossible. The order of magnitude of time required for different fuels, however, maintains the same relationship. Therefore this test can only be used as a simple analytical method to predict the effect of coal-rank and combustion gas composition on the potential carbon burnout. The ultimate usefulness of the test depends on the ability to correlate the test data with field operating experience.

In fact, examination of the test data indicates that certain fuels which are most difficult to ignite in commercial boiler furnaces, such as graphite and meta-anthracite, have burning rates above 1,600° F equal to or better than many highly ignitable anthracites and petroleum cokes. Again it has been demonstrated that reactivity is probably the single most important combustion index.

No substantial data were found covering the burnout of pyrites, but this phase of combustion is of secondary importance and probably can be controlled through proper flame shape, secondary air introduction, and residence time. Data by Linkson (25) indicate the reaction time for the thermal decomposition of FeS_2 to FeS in a nitrogen environment at about 1,200° F as shown in Figure XI-30. The decomposition rate of pyrite appears to compare favorably with that of coal. (The curves of Figure XI-31 can be superimposed on the curves of Figure XI-29 to judge relative weight-loss rates.) The reduction in reaction time with a reduction in particle size is an encouraging factor,

FIGURE XI-31



THERMAL DECOMPOSITION OF FeS_2 AT 1200°F (25) especially since the particles are so much larger than in the coal tests (250 microns vs. 0.35-0.61 cm). However, these initial indications are to be tempered somewhat by the fact that the data plotted in Figure XI-31 relate to the decomposition of FeS_2 (in this case marcasite) to pyrrhotite in a neutral atmosphere. While these reaction rates would probably be greater in an oxidizing atmosphere, the progress of combustion of FeS to Fe_2O_3 can be expected to follow at a much slower rate. Furthermore in mixtures of coal and pyrite having high pyrite concentration, the lower heating value of pyrite will result in a lower flame temperature and consequent lower burning rate.

Generally speaking, more combustion data on the burnout phase of pyrite and pyritic blends are definitely needed. A simple test should be developed which can be run in the laboratory as a standard analytic procecure to yield results fairly close to actual field trials.

4.2.6 Heating Value of the HSC Fuels

If the ultimate analysis is available, the heating value of these fuels may be obtained by a modified Dulong formula:

$$\text{Btu/lb.} = 14,600\ C + 62,000\ (H - \frac{O}{8}) + 4,050\ S + 3,000\ FeS_2$$

where C, H, O, S and FeS_2 are expressed as fractional weights of carbon, hydrogen, oxygen, sulfur and pyrite respectively as determined by the analysis of the fuel.

The heating values have been calculated for various blends under consideration, and have also been checked in the laboratory with values determined in a calorimeter; both calculated and experimental results appear in Figure XI-32.

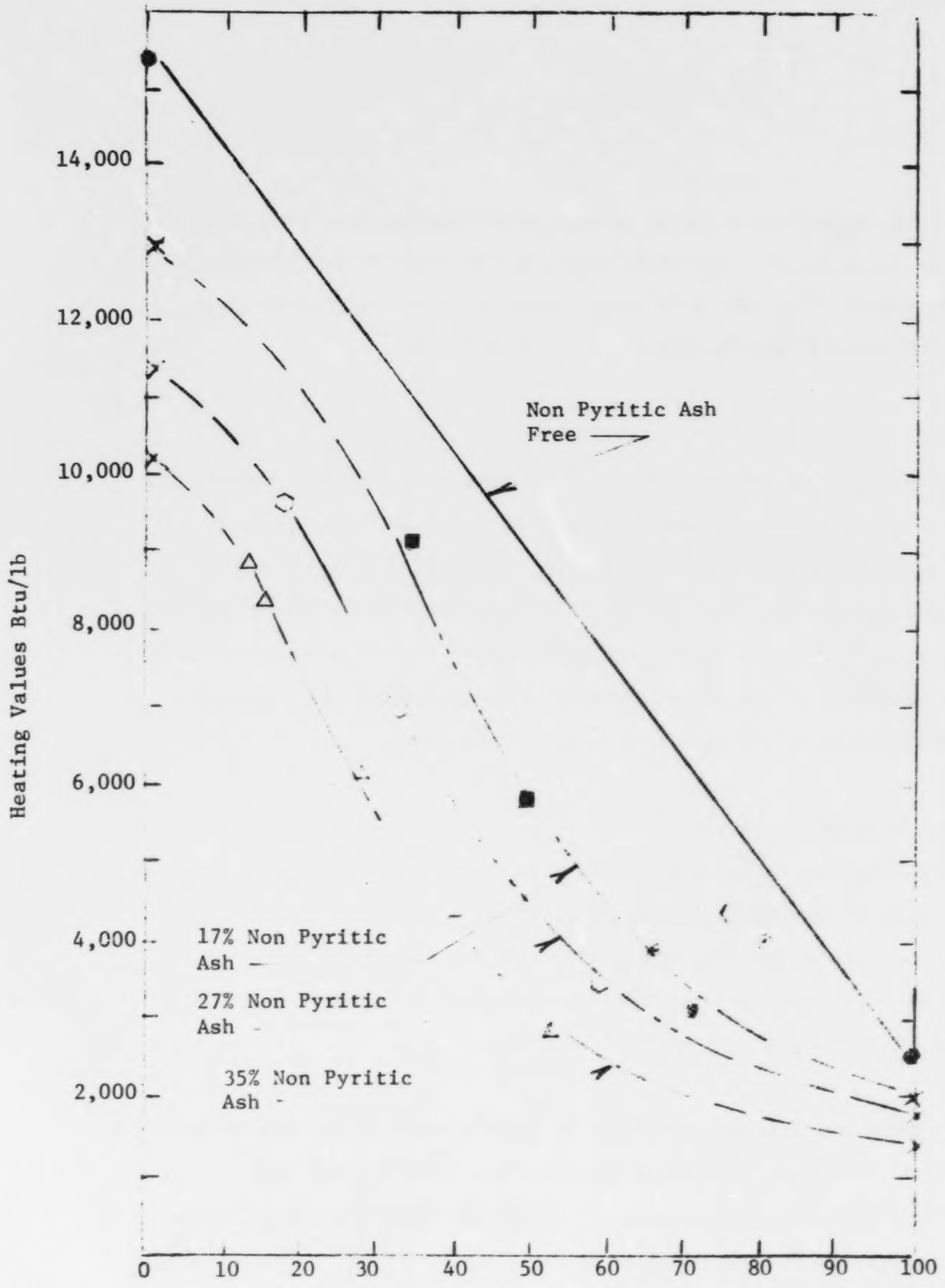
The combustion reaction above also indicates that the theoretical air requirements per pound of fuel diminish with an increase in the quantity of pyrites in the blend. Despite this lower air requirement, the very low heating value decreases the adiabatic flame temperature, which tends to retard rather than accelerate the reaction. This is compounded by high excess air requirements necessary to insure proper combustion.

4.2.7 Free Swelling Index

When blending coals with pyrites, care must be taken in selecting the type of coal used to avoid additional loss in efficiency from excess carbon and damage to burners due to coking. The latter can be a problem in the presence of large quantities of pyrite and the resulting low ignition temperature.

A coking coal has the tendency to agglomerate when heated in the furnace and pass through a plastic state during which the individual pieces fuse together into large masses of semi-coke. In pulverized fuel type furnaces, coking or caking coal tends to

FIGURE XI-32



HEATING VALUES OF BLENDS OF COAL, ASH AND PYRITE
VS PYRITE CONCENTRATION

form a glazed coating over partially spent coal particles, thereby inhibiting the further combustion of the remaining fixed carbon. The result is a high loss of heat value during combustion.

The free swelling index, used for categorizing the caking or coking coals, is determined by heating a one-gram sample of a coal which has been freshly ground to pass a No. 60 sieve under certain fixed conditions. The shape of the residue is then compared with a series of standard profiles which are numbered from 1 to 9; the higher the index, the greater is the swelling of coal. Coals with an index greater than 4-5 are considered coking coals, and are not recommended for HSC Fuels.

4.3 Fouling And Corrosion

4.3.1 General Characteristics

The fouling of boiler heat transfer equipment on the fire-tube side is often caused by the impurities found in coal, including silica, alumina, iron, titanium, phosphorus, calcium, magnesium, sodium, potassium, and sulfur. Two general categories of fouling are discernible and are distinguished by the location of deposit formations, the local operating conditions, the chemical composition, and the physical structure of the deposit.

The first category includes the slag formation type of fouling in which deposits are generally found on the furnace or tube surfaces located in the path of combustion gases where the temperatures exceed 1,900° F. Strictly speaking, the gas temperature limitations are dependent upon the softening temperature of the ash as measured under reducing conditions. Slags are usually formed by the major constituents found in the coal ash which includes Al_2O_3, SiO_2, Fe_2O_3, CaO, and MgO; sodium, potassium, and phosphorus are considered to be minor constitutents, but also do contribute to slag formation in a minor way. Under normal operating conditions, slags are soft or fluid, but upon sufficient cooling, they become solid.

The second category includes bonded deposit type fouling which is usually found in the convection-heat transfer zones where gas temperatures have dropped below the softening temperature of the coal ash. On occasion, when moisture content of the fuel is high and the flame temperature low (as in the case of Australian brown coals), bonded deposits have been found in the furnace. The deposits include all impurities found in the coal ash and on a bulk analysis are frequently in the same proportion as found in the coal. Analysis of the ash layer by layer, usually reveals a preponderance of the highly volatile material at the tube surface where the temperatures are the lowest. These deposits consist of sulfur and the minor constituents such as sodium, potassium, and phosphorus. The deposits can be in the form of a powdery material or a nearly fused particulate matter, and result from the bonding of dry fly ash particles with liquid which is solidifying at the interface or particle surface. This fluid phase, or liquid, is deposited as the result of the condensation of sulfates of minor constituents.

Further evaluation of the fouling characteristics requires an examination of the mineral impurities that might occur in the fuel. After reviewing the nature of slag and bonded deposit constituents, limits can be set on specific impurities to make the HSC Fuel acceptable from a fouling standpoint.

4.3.2 Mineral Impurities

The elements which influence fireside tube fouling most extensively have already been indicated; these include Al_2O_3, SiO_2, Fe_2O_3, CaO, MgO, Na_2O, K_2O, TiO_2, P_2O_5, and S. Since bituminous coal is most likely to be selected for the deep cleaning process on the basis of availability and iron-sulfur composition, the chemical composition of the ash may be expected to fall in the range of values appearing in Table XI-7. Selvig and Gibson have indicated the mineral form in which the impurities may be expected to be found, as listed in Table XI-8.

Although the ash that will be fired in the combustor is pure coal ash, its composition will be quite different from raw coal due to the separations effected during cleaning. As Table XI-8 indicates, iron occurs primarily as FeS_2, and to a lesser extent as magnetite (Fe_3O_4) in shale; pyrite has a specific gravity of 5, as compared to the mean specific gravity of 2.90 for the remaining constituents. Since pyrite does occur as discrete particles disseminated throughout the coal, a good separation should occur between pyrite and the remaining portion of the coal ash, leaving an iron depleted ash, referred to as non-pyritic ash, and an iron rich ash, referred to as pyritic ash. If it is necessary to blend the non-pyritic ash to recover carbon, the iron composition of the high sulfur fuel will become diluted by alumina, silica, etc. The compositions of the ash as fired will remain rich in iron with the content somewhere between raw coal ash and pure pyrite.

No evidence yet exists to indicate that the remaining constituents appearing in the non-pyritic ash are redistributed to any extent by the separation. Until such data are provided, this assumption appears to be reasonable.

TABLE XI-7

Typical Limits of Composition of Ash in Bituminous Coals

Constituent	Range, %		
$Si0_2$	20	-	60
Al_20_3	10	-	35
Fe_20_3	5	-	35
Ca0	1	-	20
Mg0	0.3	-	4
$Ti0_2$	0.5	-	2.5
$Na_20 + K_20$	1	-	4
$S0_3$	0.1	-	12

TABLE XI-8

Characteristic Minerals in Coal Ash

Group	Typical Species and Approximate Formula	
Shale	Muscovite (common potash mica),	$K_20. 3Al_20_3. 6Si0_2. 2H_20$
	Illite (soda mica),	$Na_20. 3Al_20_3. 6Si0_2. 2H_20$
	Montmorillonite (clay),	$(Mg, Ca)0. Al_20_3. 5Si0_2. nH_20$
Kaolin	Kaolinite (clay),	$Al_20_3. 2Si0_2. 2H_20$
	Metahalloysite,	$Al_20_3. 2Si0_2. 4H_20$
Sulfide	Pyrite and Marcasite,	FeS_2
Carbonate	Calcite (limestone),	$CaC0_3$
	Dolomite,	$CaCO_3. MgC0_3$
	Ankerite,	$2CaC0_3. MgC0_3. FeC0_3$
Chloride	Halite (common salt),	$NaCl$
	Sylvite,	KCl
Accessory Minerals	Occurring in minor quantities associated with the Shale Group	
	Quartz,	$Si0_2$
	Felspar,	$(K, Na)_20. Al_20_3. 6Si0_2$
	Garnet,	$3CaC0. Al_20_3. 3Si0_2$
	Hornblende,	$Ca0. 3Fe0. 4Si0_2$
	Gypsum,	$CaS0_4. 2H_20$
	Apatite,	$9Ca0. 3P_20_3. CaF_2$
	Zircon,	$ZrSi0_4$
	Diaspore,	$Al_20_3. H_20$
	Magnetite,	Fe_30_4
	Hematite,	Fe_20_3

Further examination of Table XI-7 indicates that the percent sodium, potassium, calcium, magnesium, etc., is small compared to the Al_20_3, $Si0_2$, and Fe_20_3. Since a portion of the minor constituents is removed during separation, it is reasonable to assume that the system consists of Fe_20_3-Al_20_3-$Si0_2$ components almost entirely.

Up to now, little attention has been given to trace elements since they have not been of consequence. However, with the concentration of ash during the separation process, it is possible that some of the trace elements may fall into the minor constituent category: Nunn, et al, (33) reported the range of trace elements that appears in Table XI-9. Of all elements tested, arsenic is probably the most important. Herzog (34), Homes (35), and Kirsch (36), found that the arsenic level in coals ranged from 1 to 197 ppm, and in one case, the concentration was reported to be 1, 560 ppm. They indicated that most of the arsenic occurred as arsenic pyrite which means that it could be separated with the pyrite and concentrated to higher levels in the final fuel. This situation per se is not alarming, however, it represents a potential hazard in that arsenic pyrite has been reported to behave similarly to sodium and potassium which, if allowed to concentrate in the fuel, can cause high temperature corrosion and fouling.

4.3.3 Slagging

The formation of a slag deposit is caused by physical transport of fused or partially fused particles entrained in the gas stream. When the particles strike the wall or tube surface, they are chilled and solidified. The strength of this attachment is

TABLE XI-9

Concentration of Minor and Trace Elements in Anthracite Ash and Burning Bank Samples

Element	Percent Of Ash		
Titanium oxide ($Ti0_2$)	1.5	to	2.0
Magnesium oxide ($Mg0$)	0.4	to	0.9
Calcium oxide ($Ca0$)	0.2	to	0.4
Vanadium oxide (V_20_5)	0.02	to	0.04
Germanium oxide ($Ge0_2$)	Trace	to	0.02
Manganese oxide ($Mn0$)	0.006	to	0.008
Arsenic (As)	Trace	to	0.01
Copper (Cu)	0.001	to	0.01
Chromium (Cr)	0.001	to	0.01
Lead (Pb)	0.001	to	0.01
Lithium (Li)	Trace	to	0.01
Phosphorus (P)	0.00	to	0.9
Gallium (Ga), Nickel (Ni), Tin (Sn), Zinc (Zn)	0.00	to	0.09
Beryllium (Be), Cobalt (Co), Tungsten (W), Molybdenum (Mo)	0.000	to	0.009

affected by the temperature and physical contour of the surface, by the directional force of impact, and by the wetting characteristic of the slag. The degree to which the slag will grow is also dependent on the fluid characteristics of the ash and the local temperature gradients. In zones where the local temperature exceeds the fusion temperature of the ash, a liquid phase will form whose rate of flow will depend on the viscous characteristics. At lower temperature, this flow will cease and the deposit will tend to freeze in place and grow to rather large thicknesses.

In order to predict the type of slag that will form and how it will behave, some understanding of the fusion characteristics of the ash is required, and how this is related to the chemical composition. Once the relationship is established, the amount of testing required to identify the behavior of the ash will be simplified. Determination of this relationship should enhance control of slagging conditions, and permit modification of these characteristics.

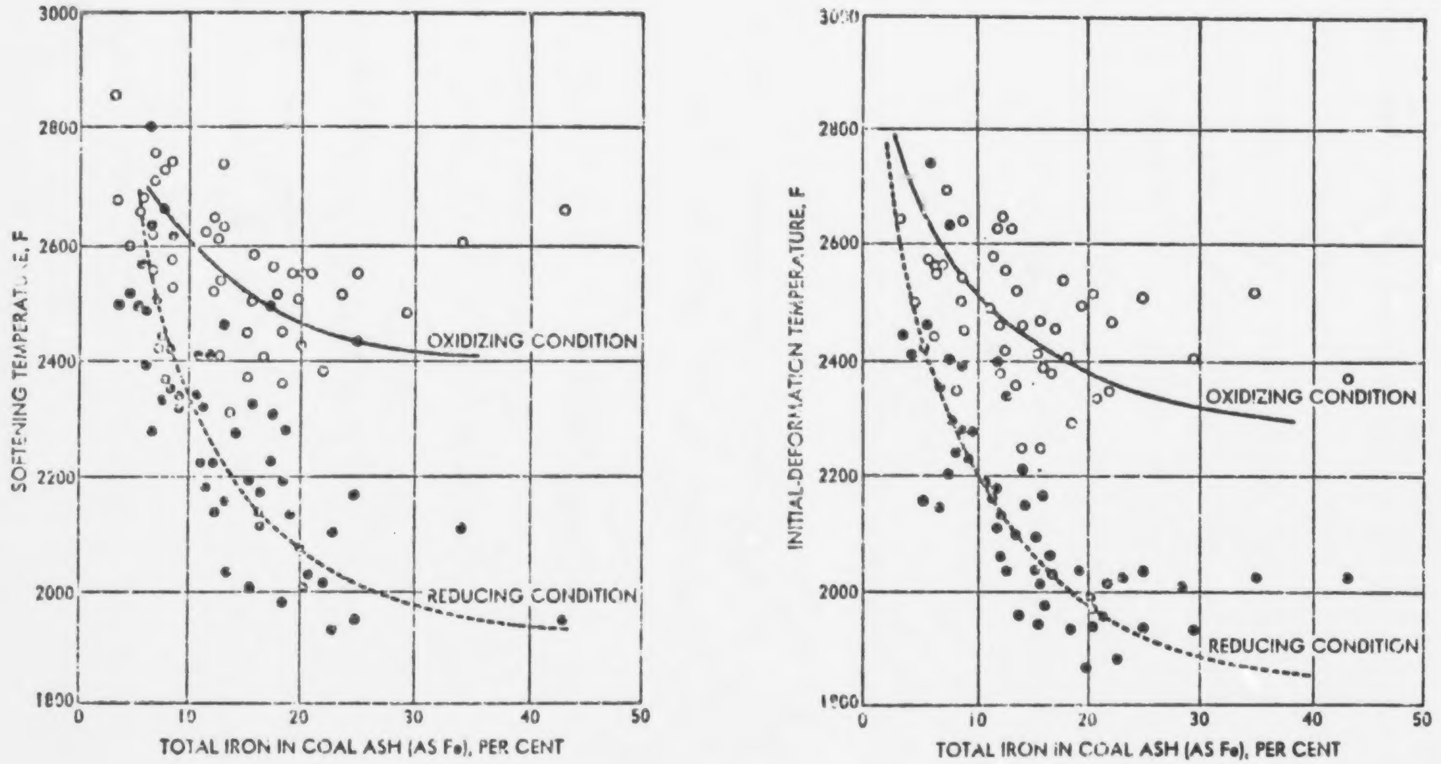
The ASTM ash fusion test has been accepted as a simple, quick method for estimating the state in which the ash will exist, i.e., liquid, solution, or solid phase. Considering the degree of accuracy of this test, it has been correlated fairly well with chemical composition. It is also a reasonably good index of conditions that are likely to exist under actual operations.

The test requires the pressing of a finely ground sample of ash into a standard mold to form a slender triangular pyramid 3/4" in height, which is set vertically upon a ceramic base within a gas-fired or electrically heated furnace. The atmosphere is maintained in a mildly reducing state by the presence of excess fuel gas or a prepared mixture. Temperatures are measured by an optical pyrometer or thermocouple. The Initial Deformation Temperature (I. D. T.) is noted when the sharp apex or edges of the specimen first become rounded; with a slow increase in temperature, melting proceeds and the Softening Temperature (S. T.) is recorded as the specimen deforms to almost spherical shape. A final measurement of Fluid Temperature is made when the ash becomes completely fused and has spread to a nearly flat liquid film upon the base. Recent experience has proven that the S. T. - hemispherical (height to half-width) shape is a more identifiable and more commonly attainable condition than the spherical shape. It occurs at a slightly higher temperature than the S. T. of spherical shape.

The S. T. value alone is frequently reported as the index of ash fusibility. Although it serves to indicate broad distinctions, it is only partially descriptive of melting behavior. Inasmuch as coal ash is a mixture, rather than a compound with a well-defined melting point, reference temperatures are significant, as well as the intervals between them which vary appreciably for different ashes. The I. D. T. is usually identified with a condition of surface stickiness, the S. T. with plastic distortions or sluggish flow, and the F. T. with liquid mobility.

Under oxidizing conditions in the test furnace, many ashes show higher values of fusion temperature than are observed in reducing atmosphere (see Figure XI-33). These differences are greater for ash of high iron content because of the variance

FIGURE XI-33



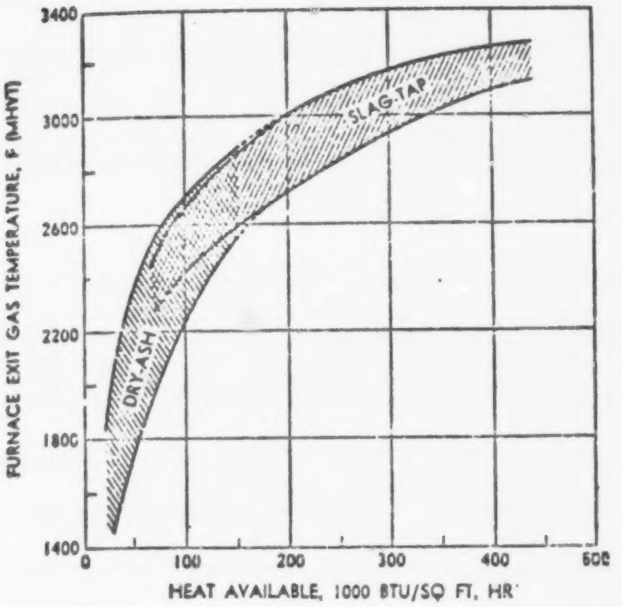
EFFECTS OF OXIDIZING AND REDUCING ENVIRONMENTS ON THE ASH SOFTENING TEMPERATURE FOR VARIOUS IRON CONCENTRATIONS in fluxing action between ferrous iron and ferric iron. Although the reducing atmosphere provides a more dependable basis for standardization of testing, and is regarded as characteristic of the fuel bed, oxidizing conditions in local areas or in other parts of the furnace may alter the behavior of the ash, independently of actual change in temperatures. For design purposes, the reducing conditions are the more reliable since they are more dominant despite the presence of large quantities of excess air or oxygen in the furnace.

The ash fusion temperatures, I. D. T., S. T., and F. T. indicate the state of the ash at various temperature levels, i. e., solid, transitionary, and completely fluid states. Therefore, considering the accuracy of the test, at least two of the temperatures, namely, I. D. T. and S. T., should represent significant points on the ash phase diagram. The I. D. T. should approximate the solidus line and the S. T. the liquidus line. The latter is of more significance in predicting fouling behavior and thus is considered the more important. It would seem reasonable to relate these temperatures to the chemical composition particularly if the system were simple. Plots of many points indicate such a curve can be drawn if the Al_2O_3 and SiO_2 are considered as one phase and the remaining constituents as the second phase. In cases where all the major constituents except Fe_2O_3 are small, the system can be reduced to either a binary of (Al_2O_3-SiO_2) and Fe_2O_3, or a ternary of all three constituents. A graph of the percent constituents present versus temperatures gives a simple from of a binary phase diagram; this can be modified to consider the effect of each of the constituents by fixing all but one constituent constant at any given time. In the case of lignite, the values of CaO and Fe_2O_3 become large, and the curve can be verified for high percentages of basic constituents by comparison of the curve with the ternary phase diagram for the Al_2O_3-FeO_2-SiO_2 system.

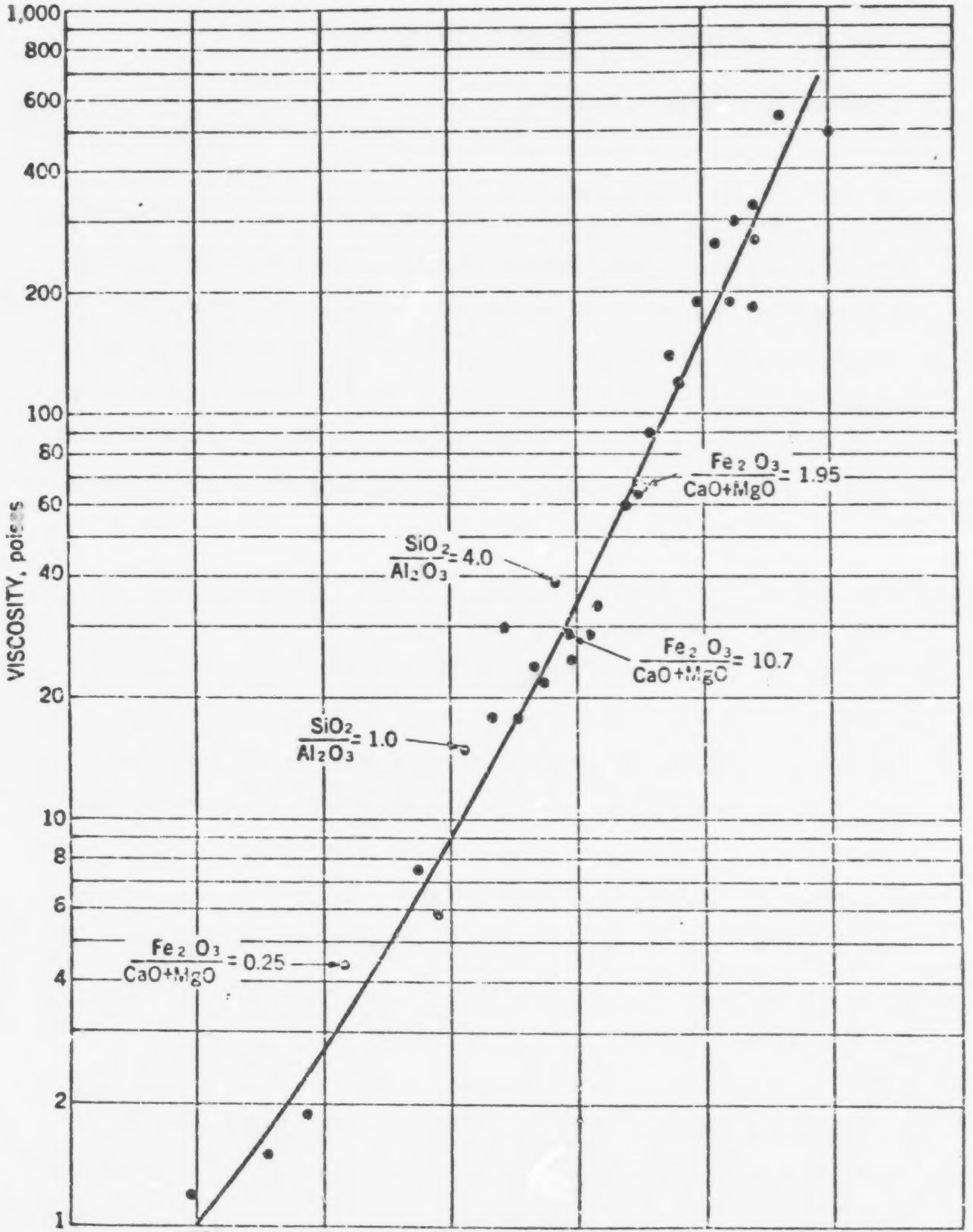
This curve is extremely important in that it indicates the conditions under which a liquid slag or dry ash can be expected. Thus, for a slag type or wet bottom furnace, the temperatures would be kept very high by using a smaller furnace where the heat available per square foot of surface was high (See Figure XI-34). In a dry bottom furnace, the temperatures would be kept at a low level to maintain a dry ash and avoid slag build-up. Generally, the borderline temperature between these two is approximately 2,300-2,500° F, the furnace exit temperature (not flame temperatures). When plotted against the heat release, it is indicative of the heat absorption and temperature gradient at the furnace wall.

In dealing with liquid slag removal, viscosity, as measured or calculated from chemical analysis, provides the most dependable guide to design. Studies have shown that at sufficiently high temperatures, all slag compositions become molten and have the characteristics of Newtonian liquids. Although widely different values of viscosity have been observed, a consistent relationship has been found to exist between viscosity and its rate of change with temperatures for specific chemical compositions. This permitted a correlation in terms of the Equivalent Silicia Content, as shown in Figure XI-35, for a temperature of

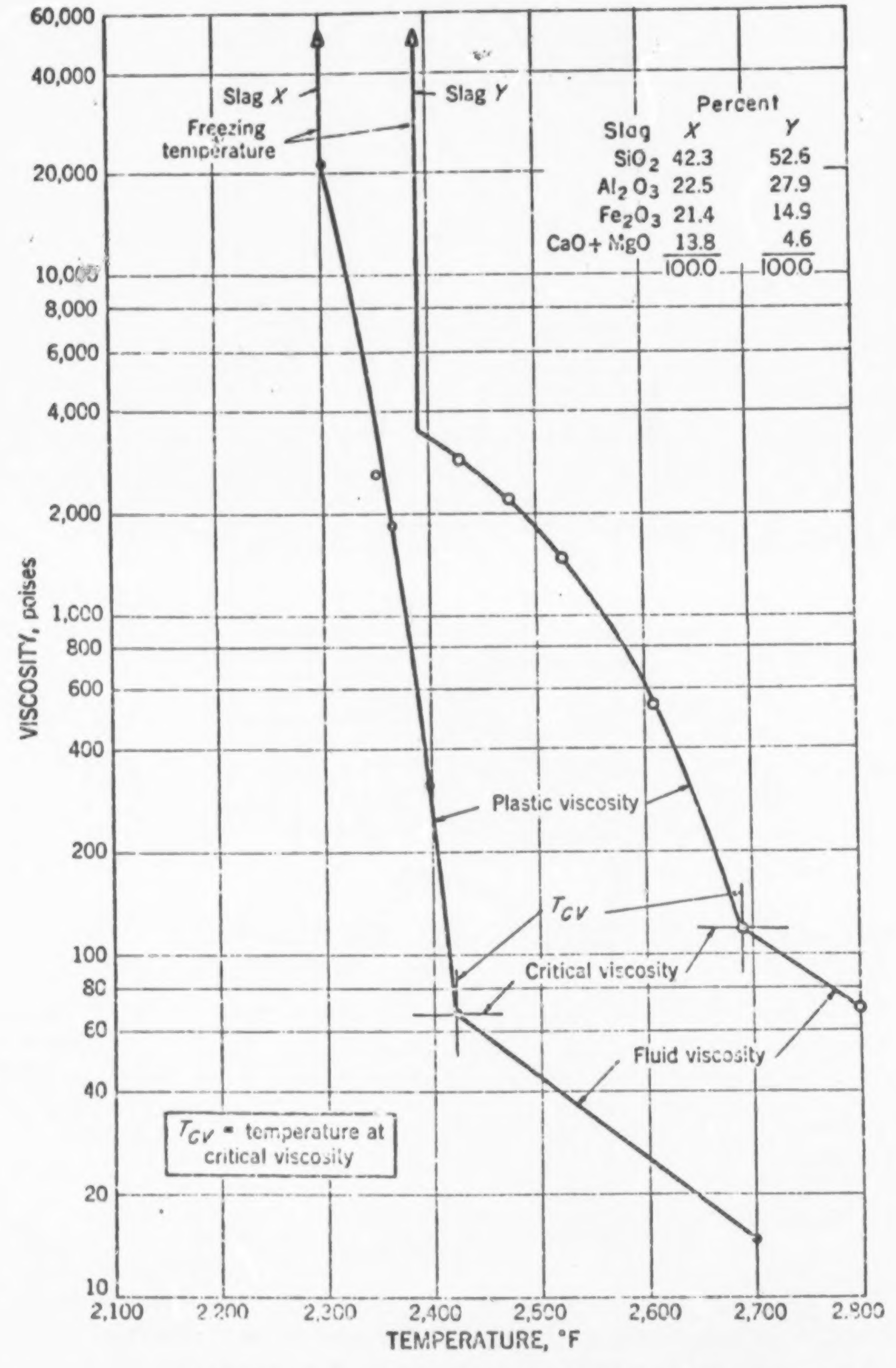
FIGURE XI-34



FURNACE EXIT TEMPERATURE VS HEAT AVAILABLE (16)



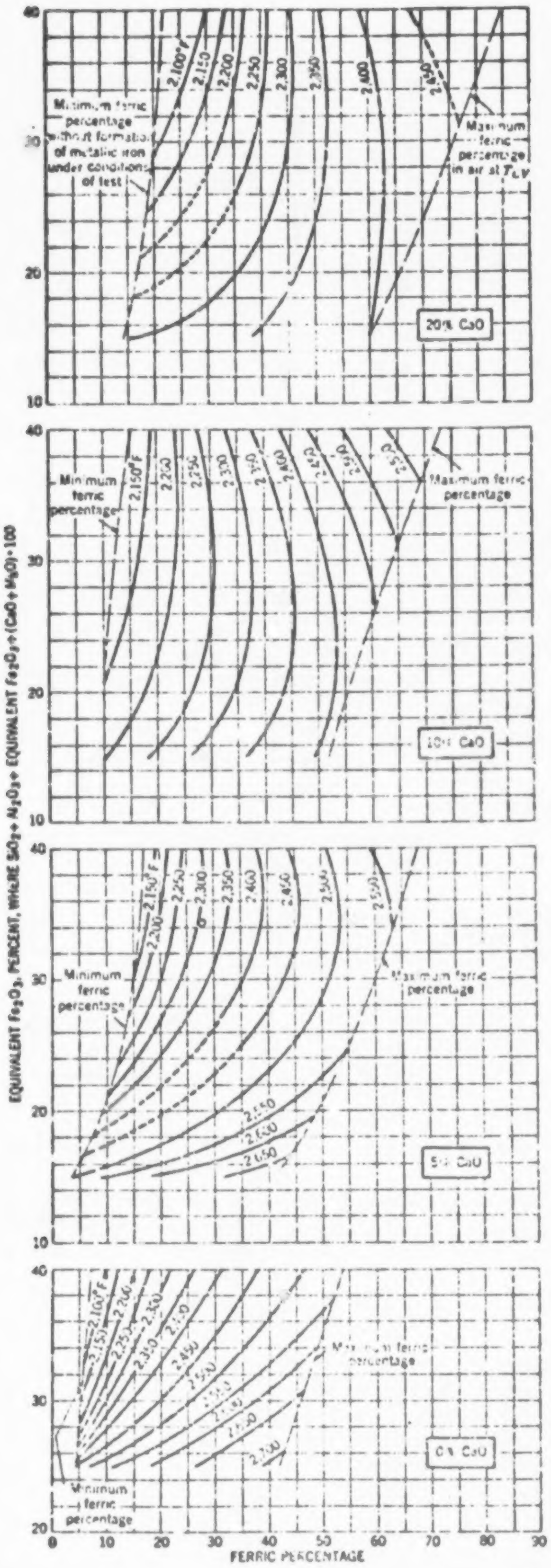
VISCOSITY OF COAL-ASH SLAGS AT 2,600°F IN AIR (39)



Slag	Percent X	Percent Y
SiO_2	42.3	52.6
Al_2O_3	22.5	27.9
Fe_2O_3	21.4	14.9
CaO + MgO	13.8	4.6
	100.0	100.0

EFFECTS OF COOLING ON SOLIDIFICATION OF TWO TYPICAL COAL-ASH SLAGS (38, 53)

FIGURE XI-37

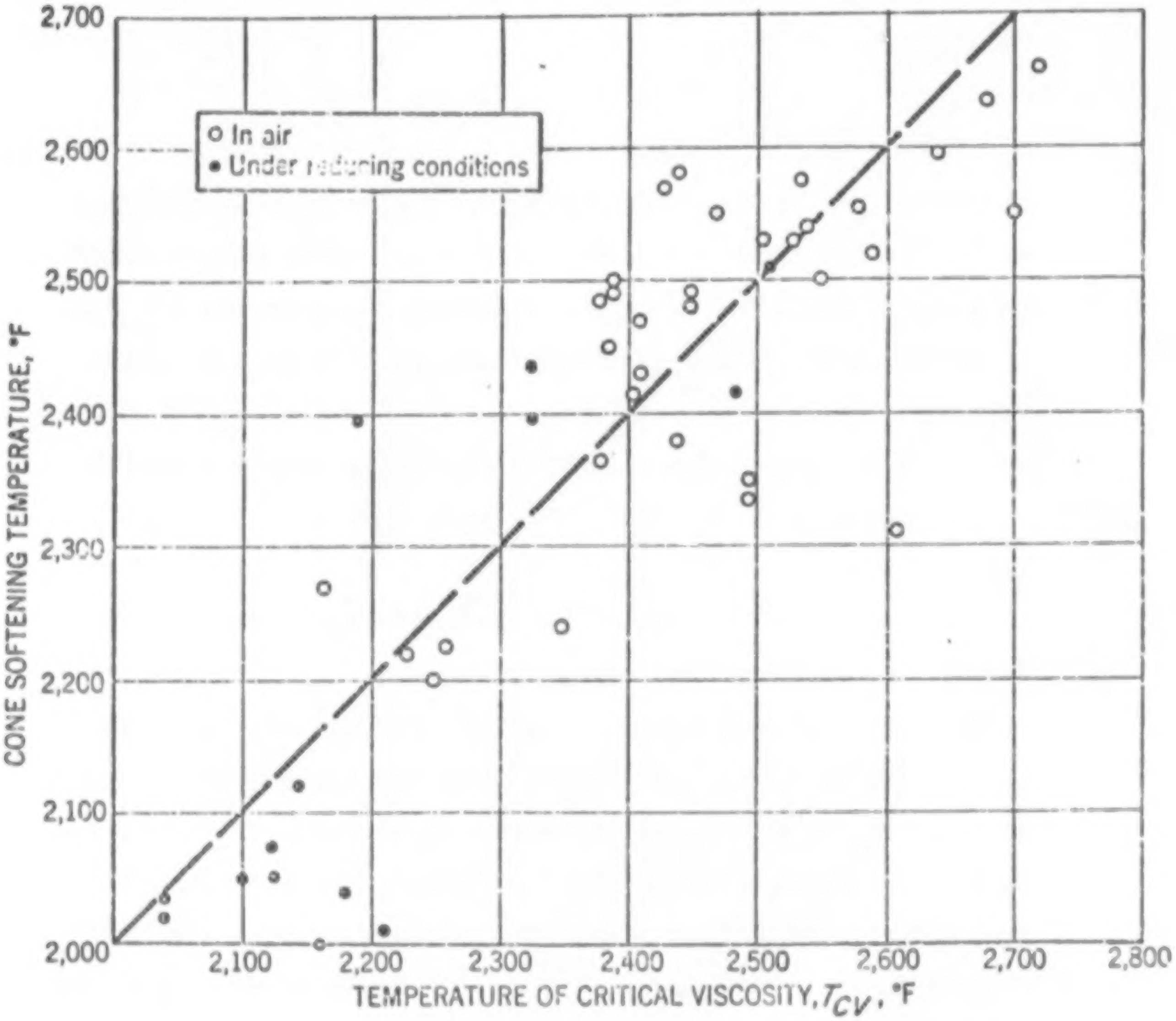


TEMPERATURE OF CRITICAL VISCOSITY OF COAL-ASH SLAGS
AS FUNCTION OF COMPOSITION AND FERRIC CONTENT
FOR A SILICA-TO-ALUMINA RATIO OF 2 (38, 53)

with the more readily obtained data on fusion temperature. Comparisons indicate that no unique value of viscosity could be identified with the I. D., S. T., or F. T. points, but a fair correlation was found between S. T. and T_{cv}. (See Figure XI-38.) Work in other laboratories has substantially corroborated the Reid-Cohen Data (38) and to some degree extended the range of investigation. Shaw (39) has presented a comprehensive review of this subject including a discussion of measuring techniques.

In boiler practice, tapping of slag in the liquid state is easily done at viscosities of 150 poises or below, and may be feasible for some compositions up to 250 poises at operating temperatures. Tapping is more difficult and may become impossible for slag approaching the plastic condition. It is therefore important to recognize the approximate transition point in furnace operation so that a margin of temperature sufficient to maintain fluidity will be provided.

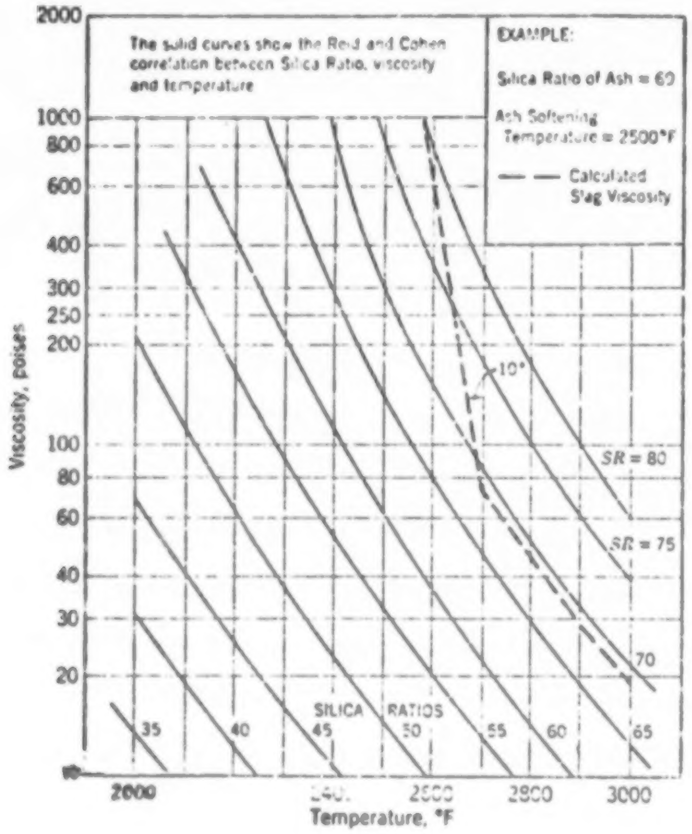
Saga and McCloy (41) describe a method of appraisal that resulted from laboratory and field investigation of United States coals; this technique employs the Reid and Cohen procedure for calculating viscosity of the fluid range and assigns an estimated value of T_{cv} at a temperature 200F° above the S. T. determined by the conventional fusion test. As shown in Figure XI-39, viscosity for the plastic range is approximated by a line drawn from this point at an angle of 10° F with the ordinate. In a more abbreviated manner which omits the chemical analysis, Heldt (42) proposed a method of estimating fluid viscosity (see



RELATIONSHIP OF CONE-SOFTENING TEMPERATURE TO TEMPERATURE OF CRITICAL VISCOSITY (53)

FIGURE XI-39

ASH REMOVAL FROM BOILER FURNACES



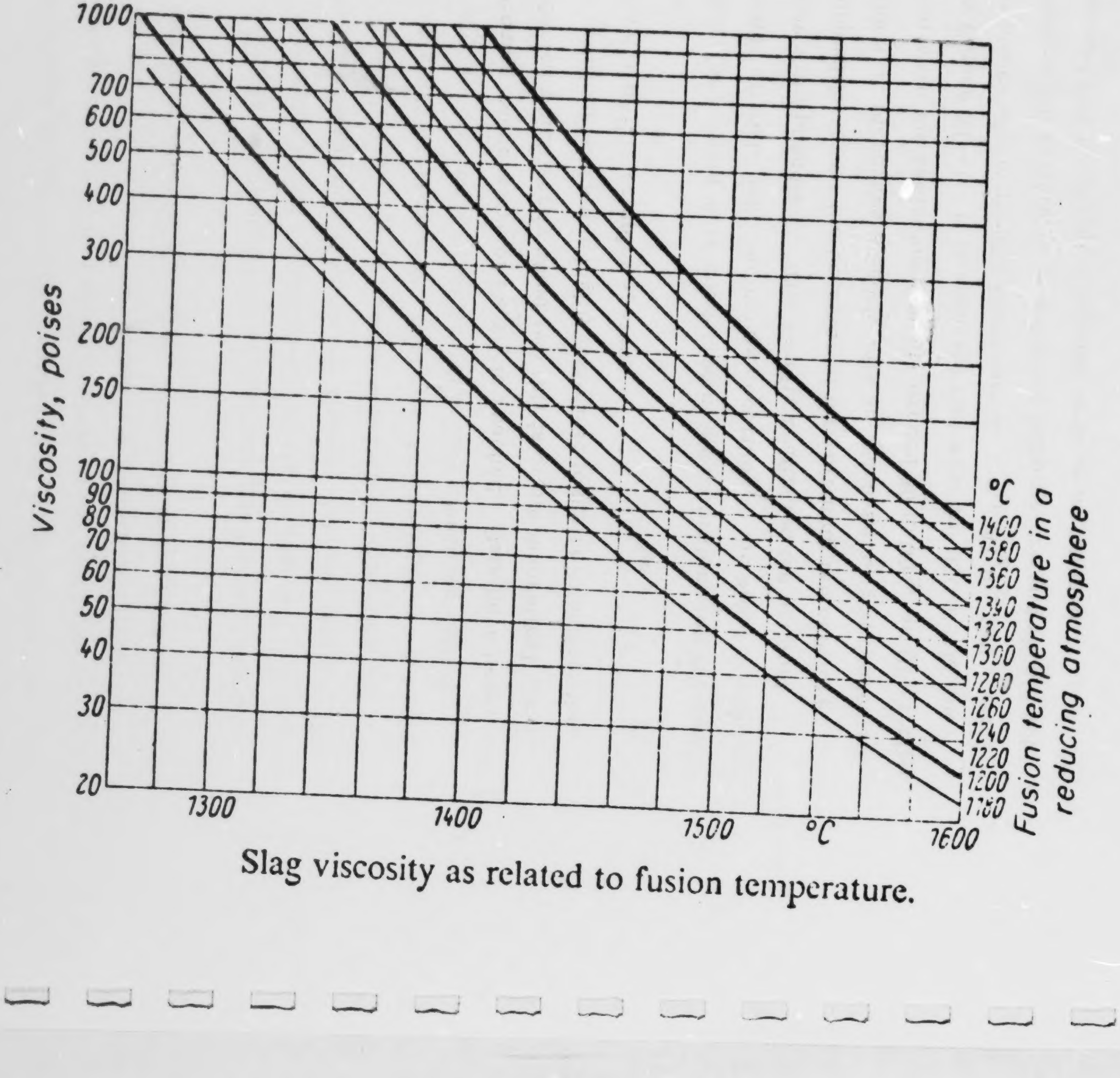
GRAPHICAL CALCULATION OF SLAG VISCOSITY (53)

Figure XI-40) based on a general correlation between the ash softening temperatures of German coals and their measured viscosity at 1, 450° C. Variation of viscosity with temperature, as confirmed by Heldt's measurements, follows the characteristic Reid and Cohen curve. This method indicates the relative ease of tapping different slags when in the fluid state, but does not identify critical temperatures of solidification.

Tapping of viscous slag can be facilitated by blending coals of suitable characteristics, or by using fluxes added to the fuel or introduced to the slag pool on the furnace floor. Compounds of calcium, iron, or alkali metals have sometimes been found effective. For slag having appreciable iron content, an increase in the fluid range may be obtained by lowering the excess air supplied to the furnace or to individual burners. Under such conditions, however, incomplete oxidation of pyrites may occur resulting in an accumulation of molten iron sulfide or metallic iron at the bottom of an inadequately drained slag pool. This accumulation can cause severe damage to the floor structure, or can solidify into a massive formation that is difficult to remove.

Handling of molten ash presents different problems. Ashes containing large quantities of the more volatile elements, such as arsenic, sodium, and potassium, have a tendency to release these substances, which condense on the high temperature heating surfaces and cause severe corrosion. It was in slag tap furnaces that arsenic corrosion was first detected (43).

FIGURE XI-40



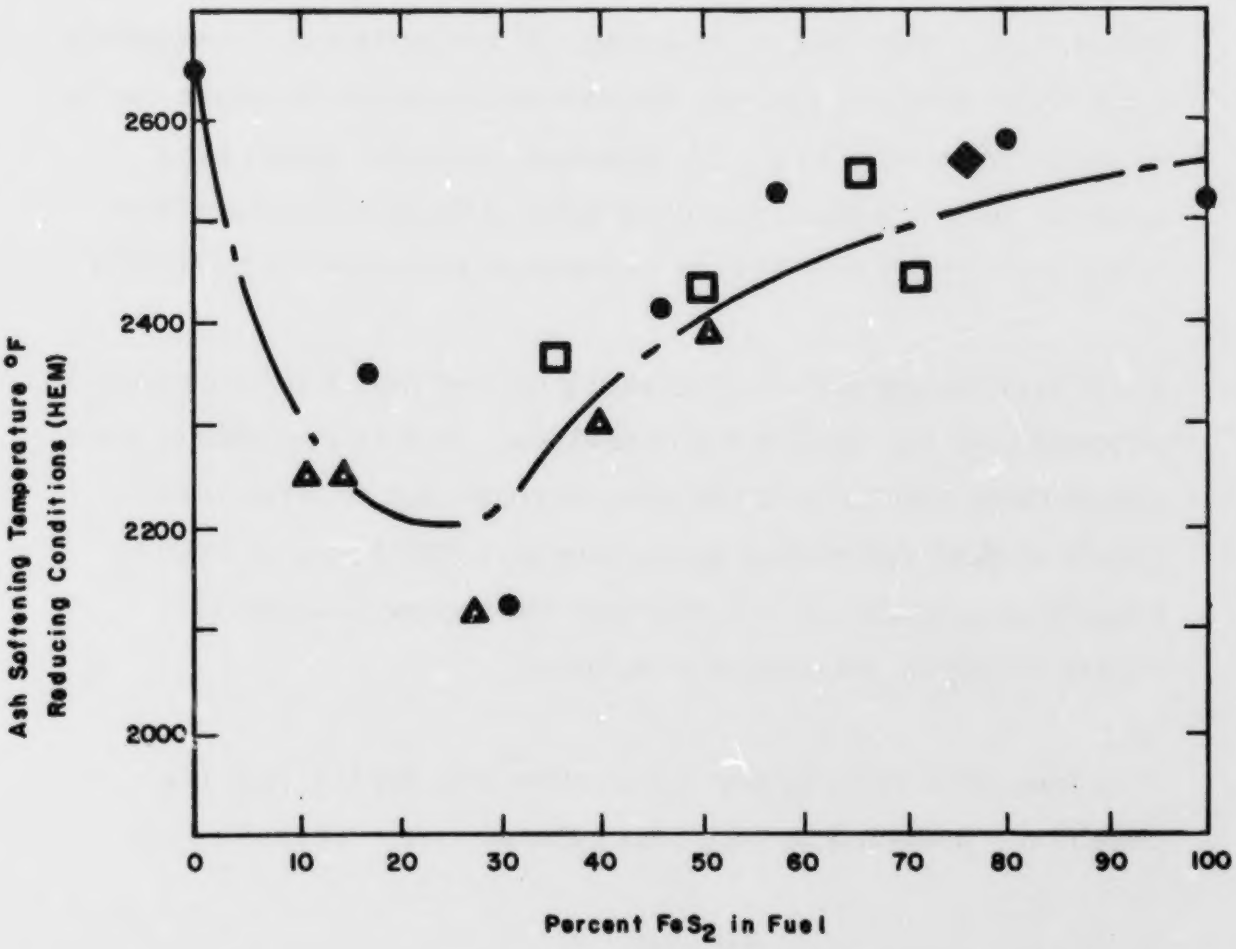
Slag viscosity as related to fusion temperature.

The discussion thus far has provided background on the coal, but has not yet been directed specifically at pyrite or blends of pyrite and coal. In order to relate this information to pyrite, further interpretation and supplementary data are needed.

The discussion has indicated that softening temperature of ash is a key index in the evaluation of ash slagging in that it sets a limit, above which one furnace is appropriate, and below which a different furnace design would be selected. The softening temperature decreases to a minimum with an increase in basic constituent content (primarily iron), then increases until the softening temperature of Fe_2O_3 is reached. Data have been collected which verify about two thirds of the theoretical curve, but additional data are highly desirable to further confirm the behavior of this complex system.

Therefore, tests were conducted in the laboratory for various blends of coal, ash, and pyrite according to the blend schedule shown in Appendix D. The results confirmed the original supposition about the behavior of the softening temperature. The S.T. increases steadily with an increase in iron concentration when the basic constituents exceed 50 to 60%, as illustrated in Figure XI-41. It is apparent that with the HSC Fuels the presence of non-pyritic constituents, i.e., Al_2O_3, SiO_2, etc., control the variations in softening temperature and should not exceed 20% by weight if dry ash is to be maintained.

In the course of heating the pyrite rich fusion cones, a liquid phase was released and drained from the cones without



ASH SOFTENING TEMPERATURE
VS FeS_2 CONTENT IN THE FUEL

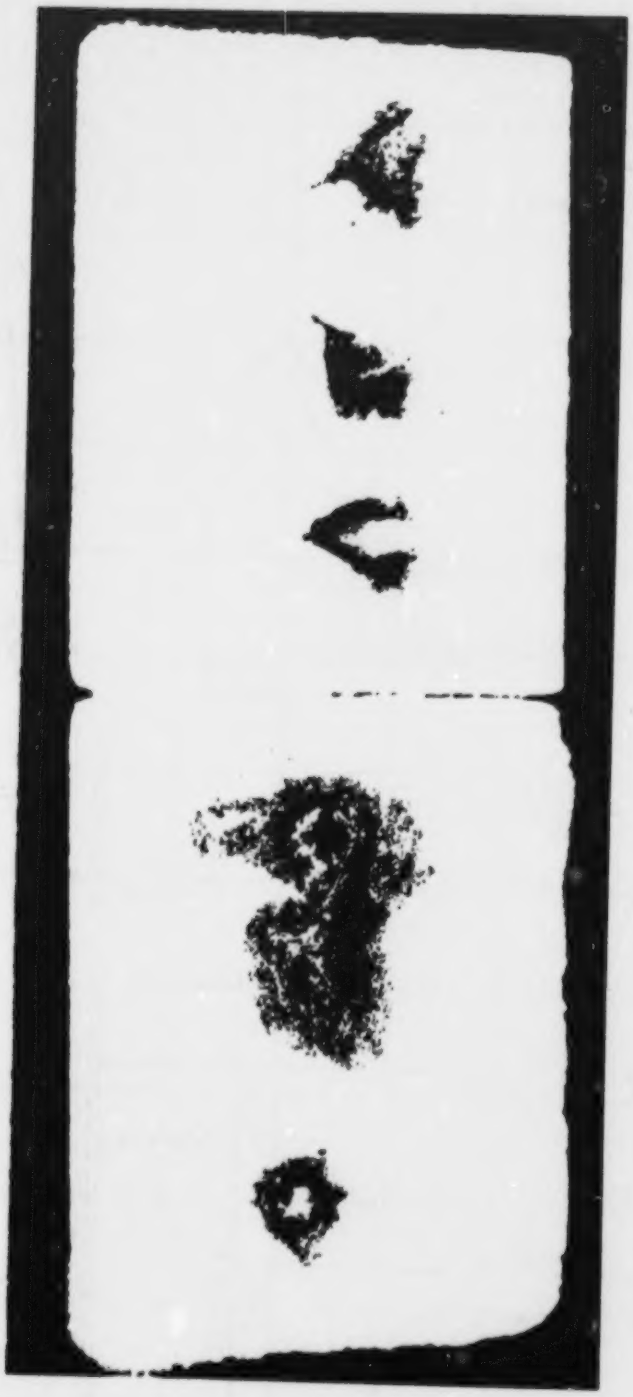
affecting the geometry of the cone. This could only be detected at the end of the experiment by a melt at the base of the cone (shown in Photograph 1). The phenomenon is due to the presence of labile sulfur which is released at low temperatures; this sulfur reacts with either FeS or Fe_2O_3 to form a low-melting phase. The phase diagrams for the Fe-S system predict melts as low as 250° F due to the presence of $FeS_2 + S$. Pyrrhotite and marcasite have a melting temperature of approximately 697° F and the melting temperature of pyrrhotite itself is about 1, 800° F. (See Figure XI-42 (44)).

In a thorough analysis of the slagging problem, the possibility of sulfide presence must also be considered, and would depend heavily upon residence time and the condition of the local atmosphere, i.e., oxidizing or reducing. If the pyrites are completely oxidized during combustion, the ash softening temperature can be expected to be very high. If, however, sulfides exist in the system, slag will form and its degree of fluidity will vary with impurities present as well as combustor atmospheric conditions.

Field experience with flash roasting of iron ore in the Outokumpu process (45, 46) confirms this analysis. In this procedure, iron ore is flash roasted in a reducing environment to form volatile (labile sulfur) and molten pyrrhotite at 1, 800° F; oil is fired to support combustion and to scavenge the oxygen present to insure a proper reducing atmosphere.

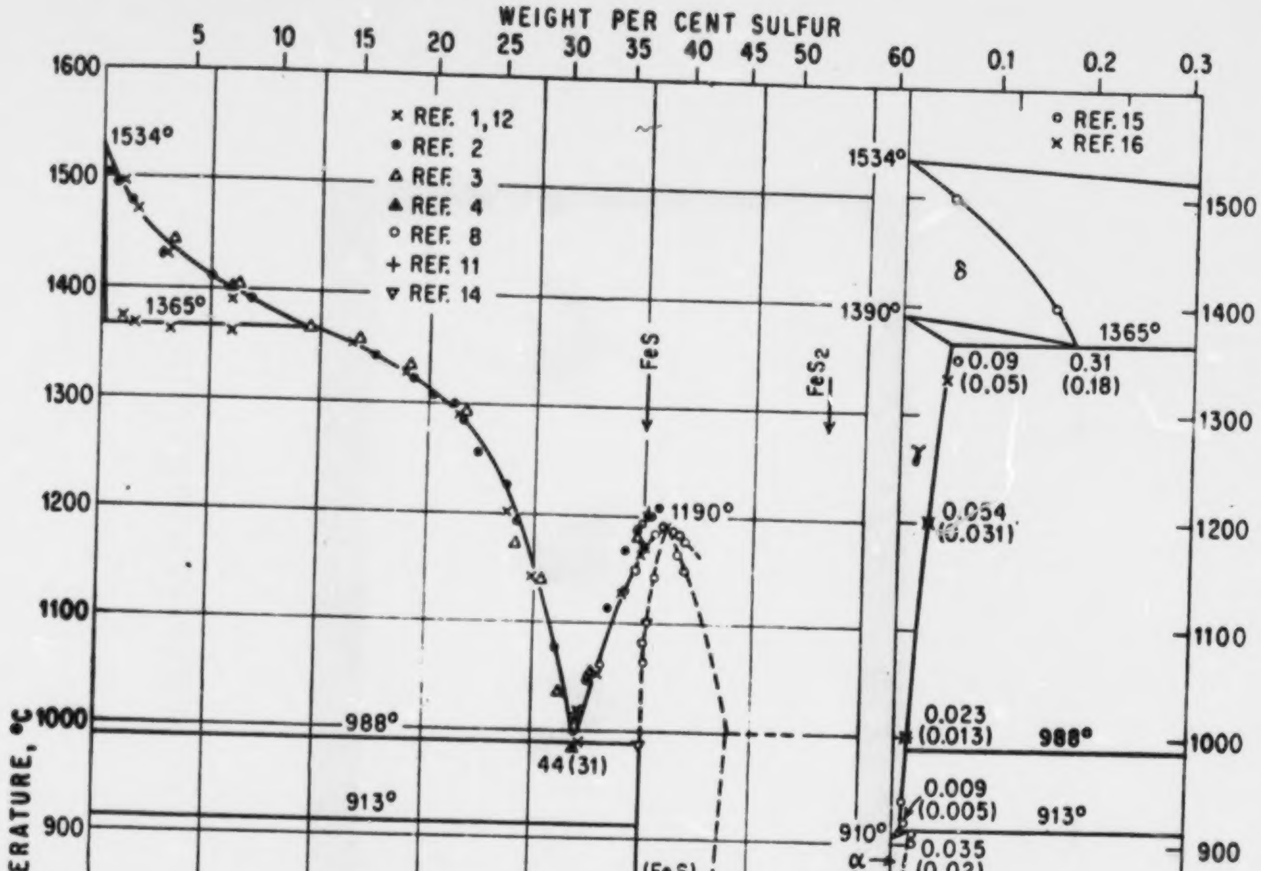
Slag formation from pyrite combustion will depend upon the excess air provided and the heat release rate. Therefore, it

PHOTOGRAPH 1


HIGH PYRITE CONCENTRATION
LOW PYRITE CONCENTRATION

ASH FUSION CONES AT DIFFERENT
PYRITE CONCENTRATIONS

FIGURE XI-42



PHASE DIAGRAM OF THE Fe-S SYSTEM (44)

appears that dry firing of ash is the most desirable mode of combustion to avoid corrosion in the furnace and the convection passes and to simplify control of the slagging conditions. Ash should remain dry if sufficient excess air is provided and the impurities are properly controlled.

4.3.4 High Temperature Fouling

Fouling in the convection passes has been categorized by various investigators into several types according to the minor constituents most frequently present in the coal. A complete list of these must include the following:

1) Alkali bonded deposits
2) Calcium bonded deposits
3) Phosphatic bonded deposits
4) Silica bonded deposits
5) Arsenic bonded deposits

4.3.4.1 Alkali bonded deposits

Alkali bonded deposits are probably the most prevalent and widely recognized type, they occur mainly on superheater surfaces and/or generator tubes in the high temperature end of the boiler. Such deposits are characterized by a high percentage of sulfates of the alkali metals. These compounds appear to act as the bonding material to hold the ash to the tube metal and to trap and cement ash particles into a hard deposit. Because of the presence of sulfates, these deposits have a high proportion of water soluble material. One mechanism to explain this formation proposes that low melting sodium and potassium compounds condense on the tube metal surface, thereby providing a sticky surface to which fly ash particles can adhere. As the composition grows in thickness, its outer surface attains higher temperatures. Eventually it exceeds the limit of condensation or stability of the inner layer. Growth continues as a result of surface bonding probably due to the reaction of the alkali and the fly ash surface. Since the inner layers are shielded by the built-up material, they cool and solidify. This mechanism is dependent upon the proper amounts of sodium oxide, potassium oxide, and sulfur trioxide being produced by the combustion process, and occurs in the temperature range of 1, 000-1, 300° F.

Operating experience over a wide range of coal has indicated that coals containing 0. 4% equivalent Na_20, on a dry coal basis, have caused little or no fouling. Potassium in this case is converted to the equivalent sodium content, so that the total alkali content in the fuel can be expressed as Na_20. Coal with more than 0. 5% (Na_20-K_20) as equivalent Na_20 has caused severe fouling of the combustion device; notable exceptions have occurred for very low sulfur content fuels. These results support the theory of the condensation of alkali sulfates, which have a melting temperature of 1, 000-1, 300° F.

The alkalis are responsible for severe high temperature corrosion, while at lower temperatures, a pyrosulfate is formed under reducing conditions which also depends on the existence of a liquid phase; this reaction proceeds in the temperature range of 650-700° F.

A third form of corrosive attack occurs as a result of the formation of alkali sulfates at very high temperatures, but its significance at this point is only academic. The corrosion may be simply summarized by the curves appearing in Figure XI-43 (47).

It is imperative that the alkalis be limited in the high sulfur combustor where sufficient SO_3 is available to form the complex alkali iron sulfates.

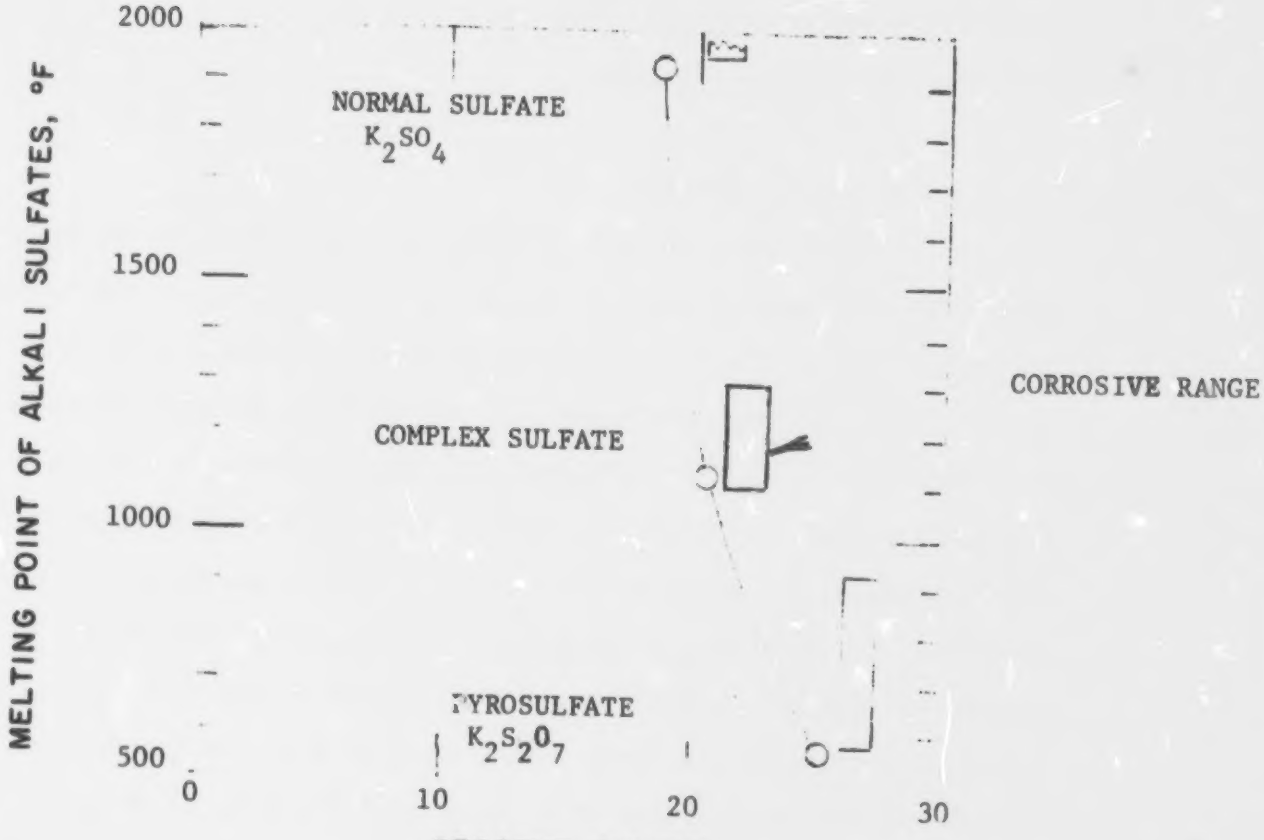
4.3.4.2 Calcium Bonded Deposits

Calcium bonded deposits are similar in appearance to the alkali type, but have a high percentage of calcium sulfate in the matrix. The mechanism by which calcium bonded deposits are formed is not clear; some investigators propose that calcium chloride condenses, while others suggest that fine crystals of calcium sulfate are deposited which, when initmately associated with ash particles, causes the two to bind together and form a deposit. Another theory suggests that the condensation of anhydrite calcium sulfate would be unlikely at the temperatures existing in a boiler; instead it is proposed that the formation of calcium sulfide occurs as an intermediate step leading to the formation of the sulfate, thusly:

$$CaS + 2O_2 \longrightarrow CaSO_4$$

The existence of a eutectic between calcium sulfate and sulfide melting at 1,530° F might indeed contribute to the formation of hard calcium bonded deposits.

FIGURE XI 43



PERCENT SULFUR

CHARACTERISTIC RANGE OF ATTACK BY THE ALKALIS AT HIGH TEMPERATURES

A further hypothesis suggests that the alkali earths MgO and CaO could be bonded by the condensation of volatile alkalis present in the fuel. In a 1:1 mixture of Na_2SO_4 and $CaSO_4$, sintering can occur at temperatures as low as 900° F - well below the melting point at 1,680° F - which could influence the formation of inner layer deposits on superheater tubes. (36)

No field data are available on which to set specific limits of the calciums, as was done in the case of the alkalis. However, with the strong possibility of labile sulfur liberation during combustion and the increased concentration of SO_3 at high temperatures, it would appear advisable to maintain the calcium concentration at a low level. Calcium input to the fuel should also be minimized to avoid lowering the softening temperatures to unreasonably low levels.

4.3.4.3 Phosphatic Bonded Deposits

The phosphatic type of deposit is similar in nature to the alkali matrix type, except that the deposit is initiated by the attack of acidic phosphorus compounds on the tube metal and on the fly ash particles. Such deposits are characterized by a high percentage of P_2O_5 and probably are initiated as a result of the formation of poly-phosphoric acids which in turn react with sodium or potassium compounds and trap fly ash particles. As long as the percentage of total ash fired is small it is doubtful that this type of deposit will form. (16)

4.3.4.4 Silica Bonded Deposits

Corrosion deposits rich in silica have been reported for stoker-fired units, and on occasion in pulverized coal-fired units. The mechanism of bonding is ill-defined and does not appear to involve a liquid phase. Normal vaporization of $Si0_2$ is negligible below 3, 200° F; within the fuel bed, however, formation of silicon monoxide (Si0) or silicon sulfides (SiS and SiS_2) may occur through the reduction by carbon or reaction with metallic sulfides. These volatile compounds are oxidized readily by encounter with excess air or water vapor. If they persist beyond the furnace, condensation may take place on tube surfaces with subsequent oxidation to $Si0_2$ (16). Nevertheless, silica should not present a problem but should be limited primarily to avoid reduction of ash fusion temperatures.

4.3.4.5 Arsenic Bonded Deposit

Arsenic is liable to concentrate together with the pyrite and therefore must be considered as a minor constituent rather than a trace element. It has been found to deposit on superheater tubes when fired with coal or oil in wet bottom furnaces. The exact amount of arsenic that causes corrosion is not known, but it appears to be related to the formation of a liquid slag. According to Kirsch (43), the high temperatures and the low viscosity of the slag must surely result in the increased volatilization of the arsenic. Arsenic exists in the flue gases as an oxide, arsenic trioxide, or possibly as the relatively high melting alkali arsenates.

Kirsch (43) indicates superheater deposits can cause corrosion when the tube wall temperatures are above 1, 040° F for ferritic steel, and (presumably) 1, 112° F for austenitic steel. The arsenic content of the deposit is unimportant. According to observations during operation, it appears as if corrosion of this type in superheaters proceeds very slowly. Frequently it was observed only after 200, 000 operating hours or longer. The speed of this corrosion is entirely dependent on temperature; an increase of 70F° above the 1, 040° F limit results in a noticeable increase in corrosion rate.

According to Kirsch the following reaction takes place:

$$AlAs0_4 + KAl(SO_4)_2 + Fe_30_4 + 7Fe \longrightarrow 1/2Fe_30_4 + 3Fe_20_3 + FeAs + 1\text{-}1/2FeS + Al_20_3 + 1/2K_2S0_4$$

Presumably all the reactions in this corrosion process occur in the solid state. The reaction does not require melts or partial melts to take place. Theoretically, these same processes can occur in the presence of a molten fluid.

It appears that arsenic corrosion can present a situation which may be further accentuated by pyrite combustion. No limits can be set regarding its concentration; however, care should be taken in utilizing a fuel with trace amounts of arsenic. Additional analysis is needed to determine the quantitative impact: all HSC Fuels should be analyzed for their arsenic content.

4.3.5 Low Temperature Corrosion

Burning of high sulfur fuels increases the potential for low temperature or dewpoint corrosion even if only small quantities of water exist. Figure XI-10 shows the influence of water on the formation of H_2SO_4 at various temperature levels according to the reaction:

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

Due to the presence of large quantities of Fe_2O_3 it is certain that sufficient SO_3 will exist to form significant quantities of sulfuric acid by reacting with the moisture available in the gas stream. The dewpoint should approach that of water-acid systems rich in acid. By correcting the dewpoint curve indicated in Figure XI-10 for the appropriate total pressure of sulfuric acid and water, the new dewpoint is determined to be approximately 400° F. Therefore, a conservative design temperature between 500 and 550° F should be used, below which the combustion gas should not be cooled until quenched.

4.4 Ash Handling

Handling of ash must also be considered in regard to the effect it may have on fouling and combustion. The best method of treatment is to relate the ash expected from pyrite to the ash normally fired with coal. Then, the total ash will be equivalent to the pyritic ash formed during combustion plus the non-pyritic ash inherently part of the coal or added to the blend. About 0.6 pounds of ash are formed per pound of pyrite fired. The non-pyritic ash has been limited to about 20% of the fuel, but for this analysis it can be considered as a parameter and investigated for various percentages. Ultimately, it would be desirable to express the total ash per unit of flue gas, or so-called ash loading, as a function of the ash fired in the fuel to provide a basis of comparison with conventional fuels.

The pounds of flue gas generated per pound of fuel decrease as the percent pyrite in the fuel increases, since iron sulfide requires less oxygen per pound to oxidize than coal. This was illustrated previously in Figure XI-2. When the total ash is converted to grains it can be related to the flue gas as shown in this figure. The basic curve is drawn for 10% non-pyritic ash and a family of curves follows at increments of 10% non-pyritic ash. The ash loading expected for conventional fuels with various ash contents is superimposed. These curves are drawn under the assumption that all the ash fired is entrained; actually in a pulverized coal unit only about 80% is entrained and this percentage drops off as the total possible ash loading increases due to agglomeration of particles, etc.

The results indicate that an HSC fuel with 77% pyrite and 20% non-pyritic ash has a total ash loading equivalent of about 55% ash in a conventional fuel. At this level, addition of non-pyritic ash has a relatively small influence on the total ash fired. However, this appears to be a marginal level regarding combustion (60% total ash) and slagging, and, therefore, should not be exceeded.

Although plants with as much as 51% ash in the coal are not common, boilers have been built to handle this type of fuel. At this level the ash handling problems are not expected to be too difficult.

4.5 Erosion

Consideration of erosion problems can only be of a qualitative nature due to the lack of published information. However some general limits can be established by logical analysis.

Erosive tendencies are more pronounced if coarse material becomes concentrated at sharp turns of the gas stream, at intercepting baffle surfaces, and at points of extreme turbulence. This effect is aggravated by an increase in quantity, abrasiveness, and velocity of coarse particles. Various degrees of erosion have been recorded in operating experience which range from harmless polishing of upstream tube surfaces, to predictable wear of induced draft fan blades and housing, to rapid localized cutting by high velocity reentrainment at the discharge edge of baffles or in the path of soot blower jets.

In studies related to gas-turbine development, erosion experiments were conducted using fly ash from pulverized coal-fired boilers in an air-jet directed against a steel surface (48). When particles larger than 10 microns were removed from the ash, a protective deposit formed on the target. Strong adherence was noted for material having a greater surface-to-mass ratio. Erosion was predominant in fly ash containing the coarser particles although both deposition and erosion occurred in some cases. Stokes reported experiments of a similar nature using silica, sand, and catalyst particles against iron and gypsum targets. Erosion rates were strongly increased by higher velocity and varied with direction of the jet, being greatest at an impingement angle of approximately 30°.

A. O. White (49) confirms this but does not indicate his source of information (See Figure XI-44) J.D. Hummel (16) classified erosion mechanisms into two categories: frictional wear, by which metal fragments are pulled or cut from the surface, and impaction, by which momentum causes local stress failure. He listed the major factors as (1) physical properties of impinging particles, (size, shape, weight, hardness, and strength), (2) velocity of particle before impact, (3) angle of impact, (4) hardness, strength, and elasticity of the eroded material, and (5) heterogeneous nature of the metal.

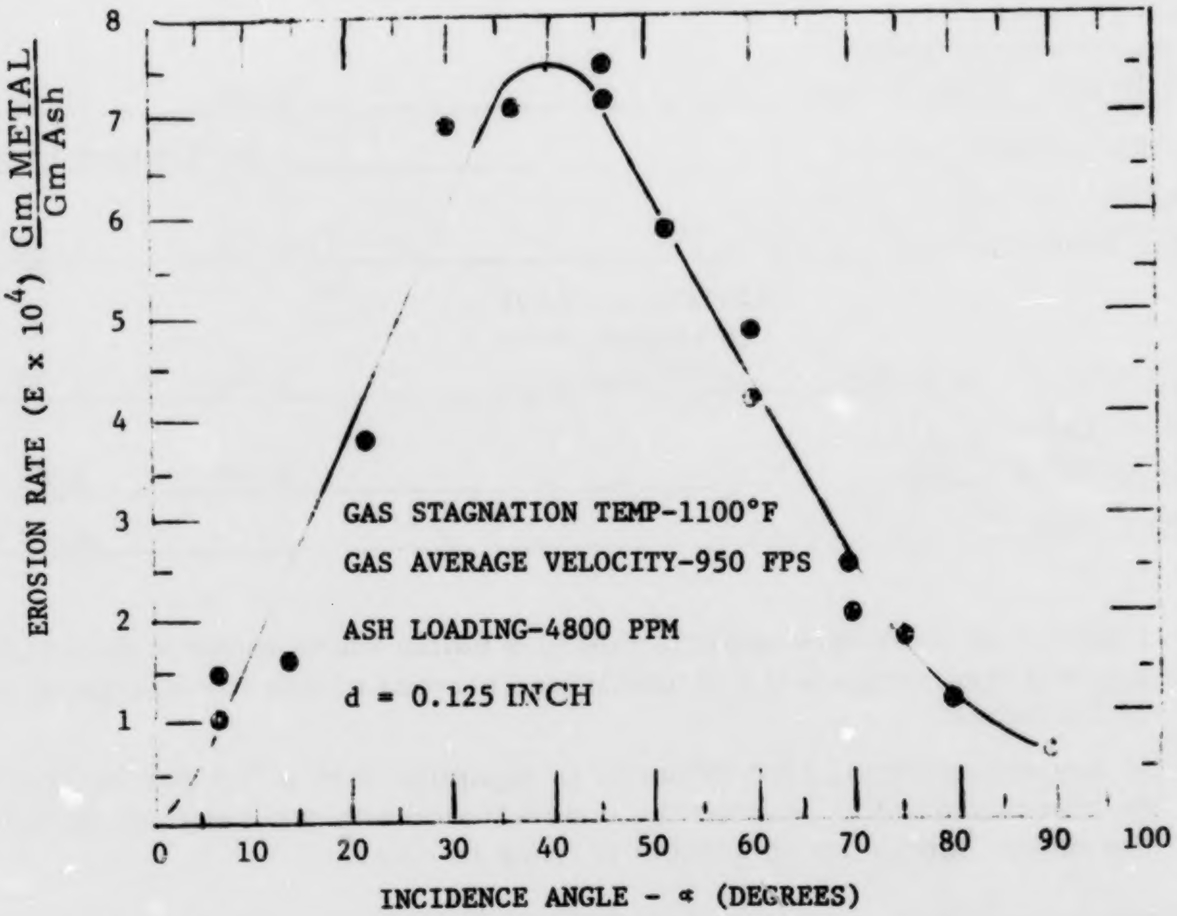
Stevens (50) indicates that some polishing of tubular surface may be expected with gas velocities of 100 feet per second. He proposed relative velocity ratios for different fuels and firing methods as shown in Table XI-10.

Since erosion is dependent upon impact of the particulate matter on the tube surface, the particle mechanics of fly ash are important to consider. A brief review of the particle mechanics should place erosion in the proper perspective as related to boiler design.

There are three basic physical mechanisms which account for the movement of particles relative to the average flow movement of the stream: (1) molecular diffusion, (2) Brownian motion or random walk, and (3) turbulent diffusion.

Molecular diffusion applies to particles so small that they approach molecular size. At this level, the proper

FIGURE XI-44 -



VARIATION OF EROSION RATE WITH INCIDENCE ANGLE ON FLAT SURFACE (49)

TABLE XI-10

EROSION LIMITS

Fuel		Apparent Allowable Velocity Ratio[3] (1)	(2)
Pulverized Coal		0.75	1.00
Spreader Stoker[4] Anthracite Chain Grate Coke Breeze Chain Grate		0.60	0.75
Cyclone Furnace		No Erosion Limit	
Underfeed Stoker Blast Furnace Gas		0.75	1.00
Bituminous Chain Grate	(Arbitrary limit-no erosion ever experienced)	1.00	1.20
Wood or Other Waste Fuels Containing Sand		0.50	0.60
Cement Dust		-	0.45

(1) Limit at or anywhere downstream of a baffle which tends to concentrate ash and then permits the concentrated stream of ash to impinge on the boiler tubes.

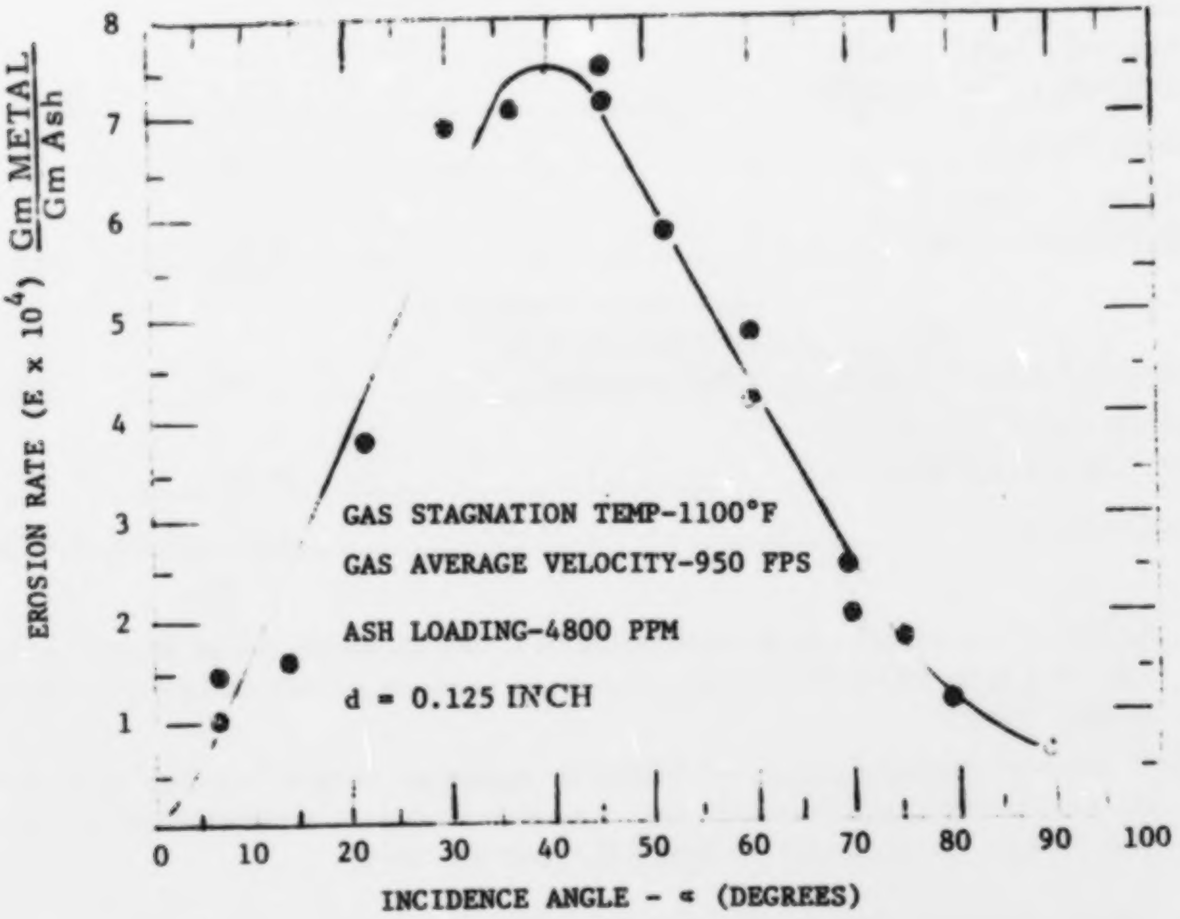
If the concentrating type of baffle is equipped with a "cinder catcher" or slot arranged to prevent the concentrated ash stream from striking the tubes, the limits in column (2) may be used.

(2) Single pass boilers or those with baffle arrangements which do not concentrate the flyash.

(3) Ratio of allowable velocity (V_a) to critical velocity (V_c) above which erosion becomes excessive. Critical velocity is not an exact value. Stevens suggests V_c should be no greater than 100 ft. /sec.

(4) Table XI-11 shows the variation in fly ash particle size which explains why lower velocity ratios may be used for some fuels.

FIGURE II-44 -



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(4) Table XI-11 shows the variation in fly ash particle size which explains why lower velocity ratios may be used for some fuels.

TABLE XI-11

TYPICAL FLYASH LEAVING FURNACE

Type of Firing		Pulverized Coal (Slag Tap)	Pulverized Coal (Dry Ash)*	Dumping Grate	Spreader Stoker	Bituminous Chain Grate
Stoker Heat Release (BTU/SqFt)				130,000	500,000	400,000
Flyash Sizing						
W.S. Tyler Screen Size	Microns					
Over 16	Over 1000	Trace		Trace	1.9	Not Available
30 to 16	450 to 1000	0.4	-	0.9	7.5	
50 to 30	300 to 450	1.1	-	1.5	10.3	
100 to 50	150 to 300	2.0	2.0	4.1	17.3	
200 to 100	75 to 150	8.5	8.0	13.0	23.8	
325 to 200	40 to 75	9.0	10.0	17.5	13.2	
Less than 325	Less than 40	79.0	81.0	63.0	26.0	
Dust Loading (Grains/CuFt at 32F)		2.5	3.5	0.4 to 0.5	1.5 to 4.0	0.25

*Thomas Reinaur, Criteria for the Application of Dust Collectors to Coal Fired Boilers, Proceedings of American Power Conference, Vol. XXIX, 1967.

molecular velocities and collision frequencies can be obtained by analytical methods based on the kinetic theory of gases. From an engineering viewpoint, the molecular mass transfer can be predicted by the same flow parameters that govern convective heat transfer. This approach of assuming that the particles behave as a gas, applies to particles of 0. 1 micron or less. As the upper limit is approached, the approximation becomes less accurate. It has also been pointed out that a low-density material satisfies this assumption better than high density particles. (16)

Brownian movement or random walk is motion that results from random bombardment by fluid molecules. Ungar and Putnam (16) indicated that the expressions derived to statistically describe Brownian motion are all based on the assumption that a particle of gas, no matter what size, moves about with a mean, translatory, kinetic energy which is a constant depending only on temperature. A lower limit is set for Brownian motion based on particle size. This limit occurs when the particle is small enough to slip between the gas molecules. The drag force in this case is described by Stokes' law which is based on a "continuous fluid". This introduces a problem when the particle size approaches the mean free path between molecules. In order to solve this problem, Cunningham and Milkham undertook to investigate the case of a particle too small to be analyzed as a sphere moving in a continuous fluid, or too large to be analyzed as a large molecule. As a result of this investigation, they were able to determine a correction factor for Stokes' law. This factor is generally applied to particles less than 3 microns in diameter. Brownian motion is most pronounced with particles of 0.1 to 3 microns. The gross effect of Brownian motion in still gas is analogous to gaseous diffusion.

The next form of particle motion is turbulent diffusion. Particles are in a state of turbulent diffusion when they are impelled to follow eddies in the stream and are hurled about. Particles are moved about by the exchange of momentum due to the turbulence of the flowing stream.

All of the regimes of motion described above relate particle motion to the average free movement of the stream. The fourth regime of particle motion deals with the movement of particles in relation to the stream as a result of a sudden change in direction of flow.

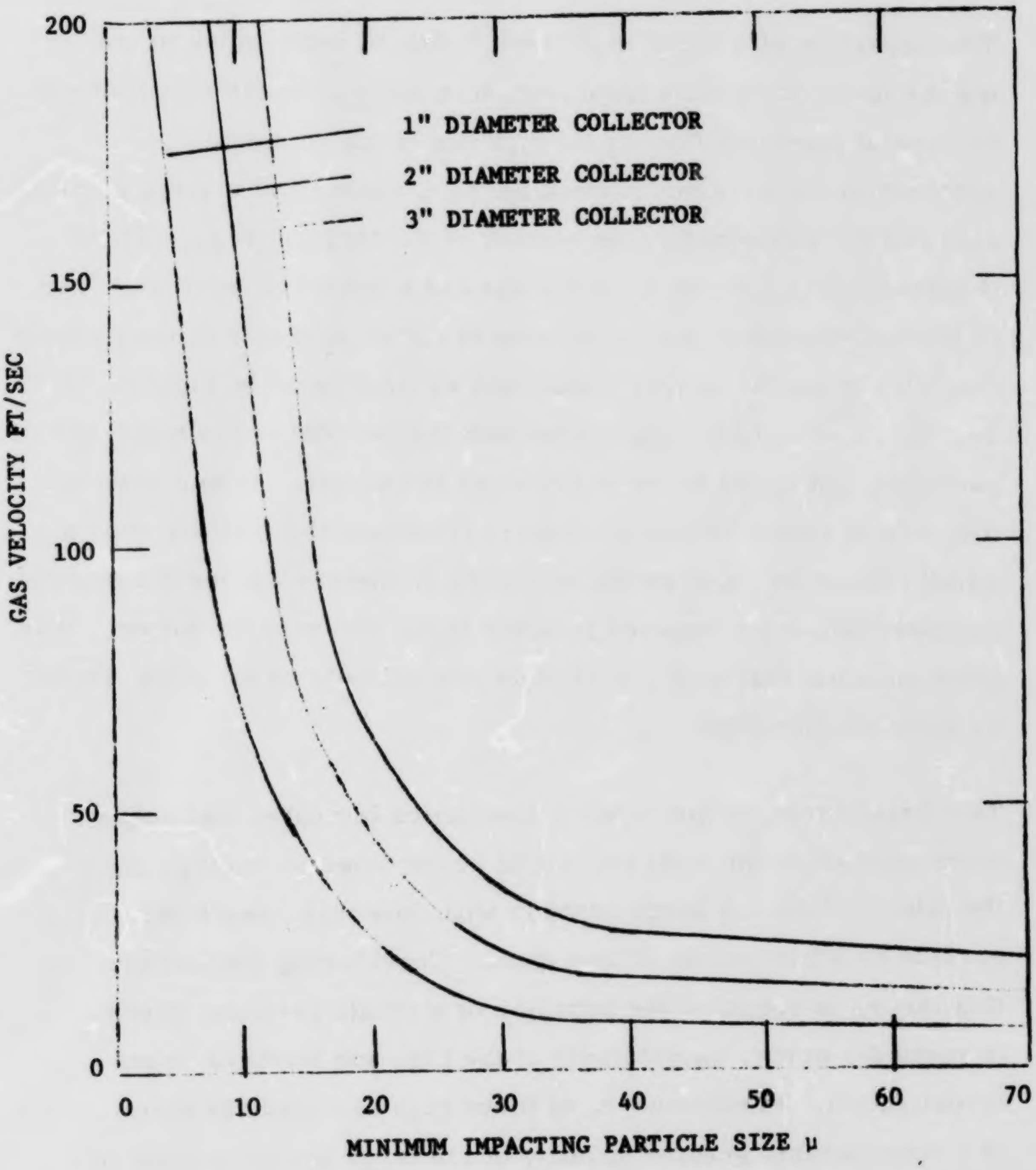
An understanding of this phenomenon involves an analysis of particle trajectory as the flue gases flow around the tubes. A detailed theoretical treatment would undoubtedly require manipulation of a rather complicated formulation before it was completed. Most investigators have found it more convenient to describe and compare particles undergoing inertial impact in terms of the inertial impact parameter "K". This factor is defined as the ratio of the stopping distance, λ_s, of a small spherical particle to the half diameter of the collecting target. Other investigators have used the full diameter of the target as reference and care must be taken to insure that the appropriate values are being used. The stopping distance, λ_s, is the distance a small spherical particle will penetrate into a still fluid if it were released with an initial velocity "U". The initial velocity or stream velocity in this case is analogus to the terminal velocity achieved by particles in still air when acted upon by gravitational forces. The expressions for the stopping distances (which may be derived from Stokes' law), the inertial impaction parameters, and Stokes' formula, appear as follows:

(1) $f = 3\pi\eta V D_P$ Drag force according to Stokes formula

(2) $\lambda_s = D_P^2 \rho_P U / 18\eta$ Stopping distance

(3) $K = \rho_P D_P^2 U / 9\eta D_T$ Inertial impaction parameter

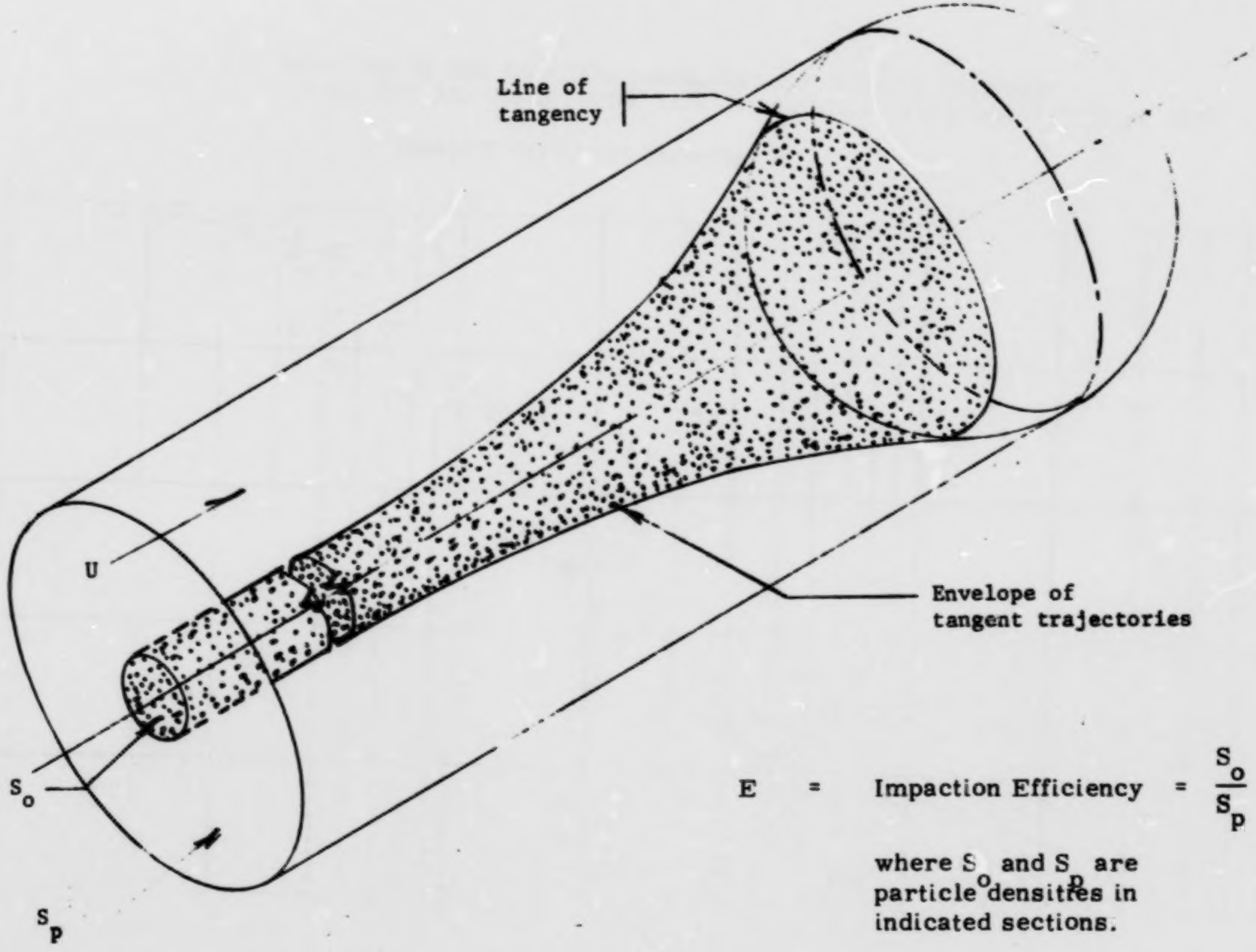
The inertial impaction parameter is particularly valuable in defining the critical particle size below which impaction on a target will not occur. Particles with diameters equal to or below the critical diameter will either graze the target at some point where its trajectory is tangent to the tube and pass by or they will remain suspended in the fluid and not come in contact with the target at all. The critical Impaction Number has been accepted as 0. 125. Using this number the critical particle size can be conveniently plotted versus the gas velocity with the target diameter as a parameter. Figure XI-45 indicates that particles less than 10 microns in size would not be expected to come in contact with boiler tubes when the gas velocities were approximately 100 feet per second or less. The curve also indicates that particles 20 microns and smaller will not come into contact with tube surfaces at velocities less than 50 feet per second. Interpretation of the graph ultimately requires a knowledge of the percent distribution of particulate



GAS VELOCITY vs MINIMUM PARTICLE SIZE FOR IMPACTION (51) matter in the flue gas. A distribution typical of a conventional pulverized coal plant was assumed and appears in Section XI-5.2.8, page 92.

The impaction efficiency is another factor of importance in analyzing the mode of particle transport; it is defined as the ration of the number of particles flowing through the cross sectional area enclosed in the envelope formed by the trajectory of a given particle size and the projected cross section of the target. Figure XI-46 illustrates this definition for the case of a spherical particle. The impaction efficiency can be expressed either in terms of the particle diameter of the impaction coefficient as illustrated in Figures XI-47 and 48. This relationship represents the percent of the entrained particles that might be expected to hit the target. At this point we may assume zero re-entrainment to illustrate the fact that only a small portion of those particles whose diameters exceed the critical diameter would be expected to come in contact with the target. It is quite possible that only a portion of this already small group would be expected to adhere.

This brief survey of particulate mechanics indicates that only a small portion of the total ash would be expected to impinge on the tube surface. A large quantity will, however, reach the surface by other modes of transport. Considering the fact that this theory is based on the behavior of a single particle, there is room for error, particularly at the high ash loadings under investigation. Furthermore, at these high ash loadings there is a considerably greater quantity of the large particles despite the fact that they represent only a small percentage of the total ash. Therefore, to avoid excessive erosion, it is advisable to maintain gas velocieites below 45 feet per second.

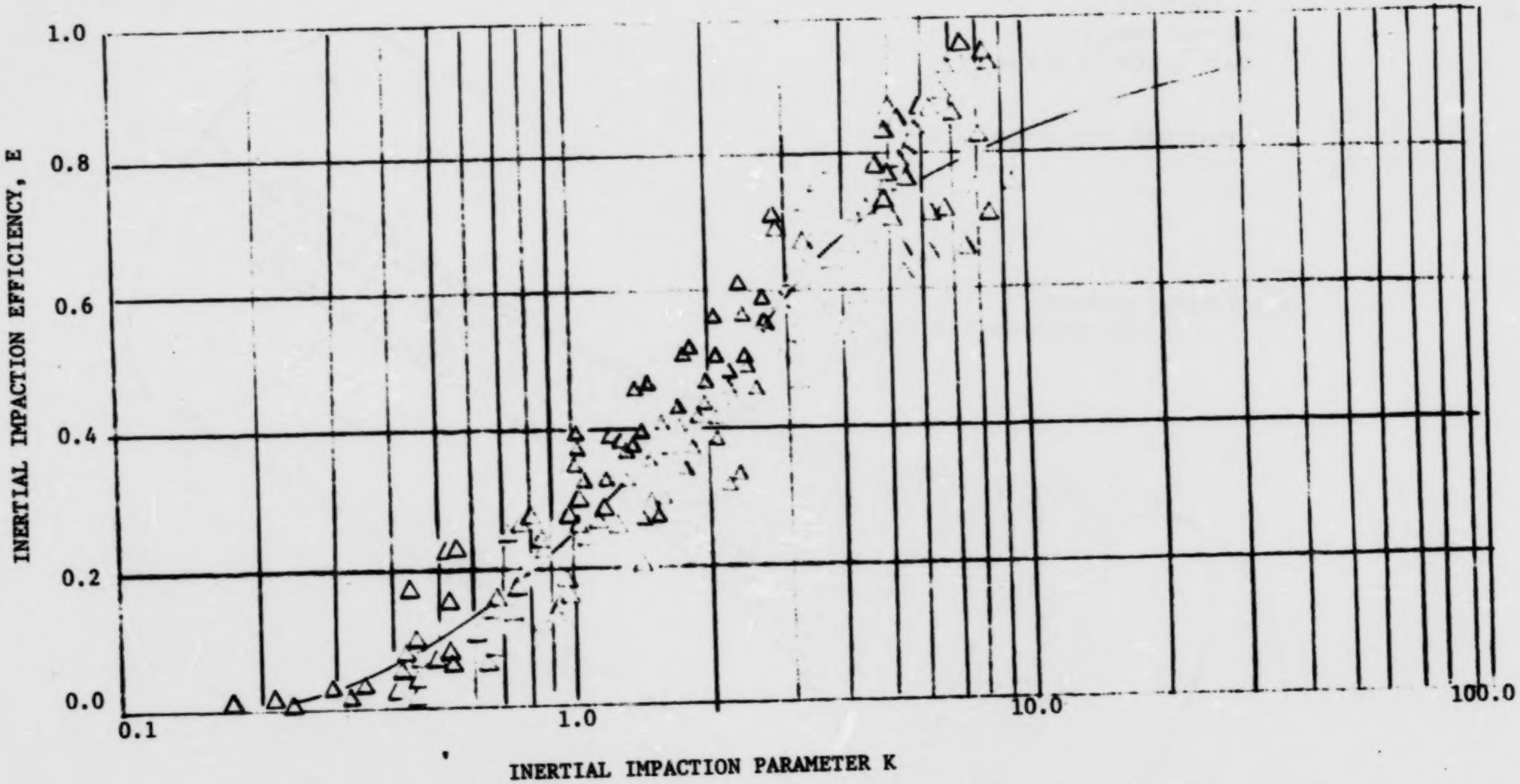

Line of tangency
U
Envelope of tangent trajectories
S_o
S_p

$$E \quad = \quad \text{Impaction Efficiency} \quad = \quad \frac{S_o}{S_p}$$

where S_o and S_p are particle densities in indicated sections.

IMPACTION EFFICIENCY OF A SPHERE, IN GRAPHIC FORM (51)

FIGURE XI-46.



THEORETICAL AND EXPERIMENTAL INERTIAL IMPACTION EFFICIENCIES, E, AS (51)
FUNCTIONS OF THE IMPACTION PARAMETER, FOR CIRCULAR CYLINDERS

FIGURE XI-47

FIGURE XI-48

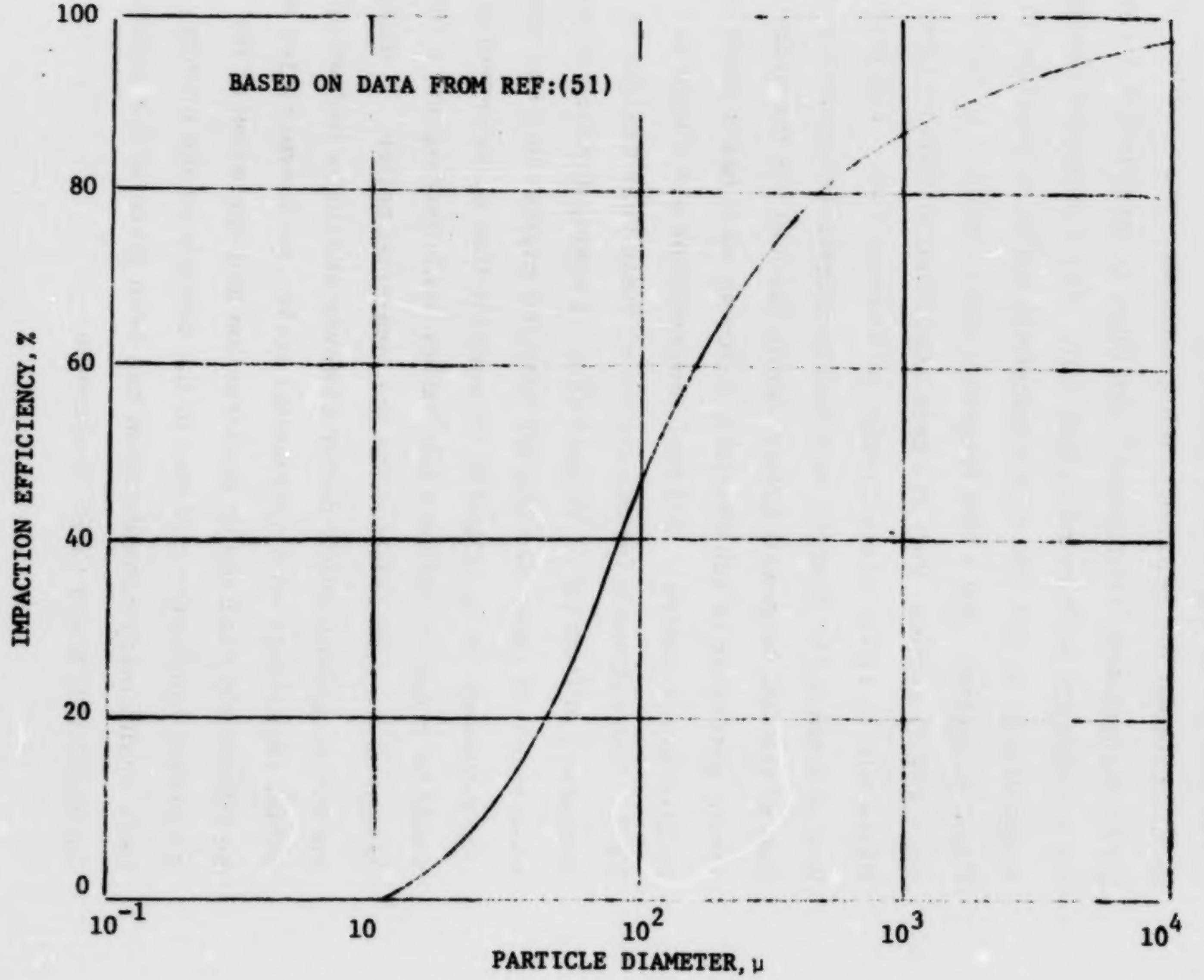


FIGURE XI-48 THE VARIATION OF IMPACTION EFFICIENCY WITH PARTICLE DIAMETER (51)

5. COMBUSTOR DESIGN DETAILS

Three designs of high sulfur combustors have been developed to a level sufficient for reliable pricing estimates to be made. Two of these designs are "conceptual"; the third is intended as a basis for a prototype or demonstration unit. The conceptual designs are, respectively, a 500, 000 lb/hr industrial boiler to function in the CASE A system, and a 500 Megawatt utility boiler, to function in the CASE D system; they are both described in Volume One, and Parts XIII and SVI, respectively, of Volume Two. The prototype unit is intended to operate on a fuel of identical composition to that of the 500 Megawatt boiler, while the fuel for the industrial steam generator is substantially different as it has a much higher pyritic sulfur content. All fuel compositions are shown in Table XI-1. The rationale for the choice of these base designs is discussed in Part III of Volume One. Looking forward to possible elaboration of these designs for detailed engineering and construction pruposes, it is judged to be unlikely that an intermediate size would be required between laboratory scale testing and a final design of the size selected for the industrial boiler. A design of the 500 Megawatt utility boiler however should [illegible] backed up with actual experience on a substantial scale: such experience would be adequately realized by construction and operation of the 50 Megawatt combustor included in the designs as the prototpye. Only preliminary consideration has been given to the combustors for the CASE B and CASE E systems.

5.1 General Design Considerations

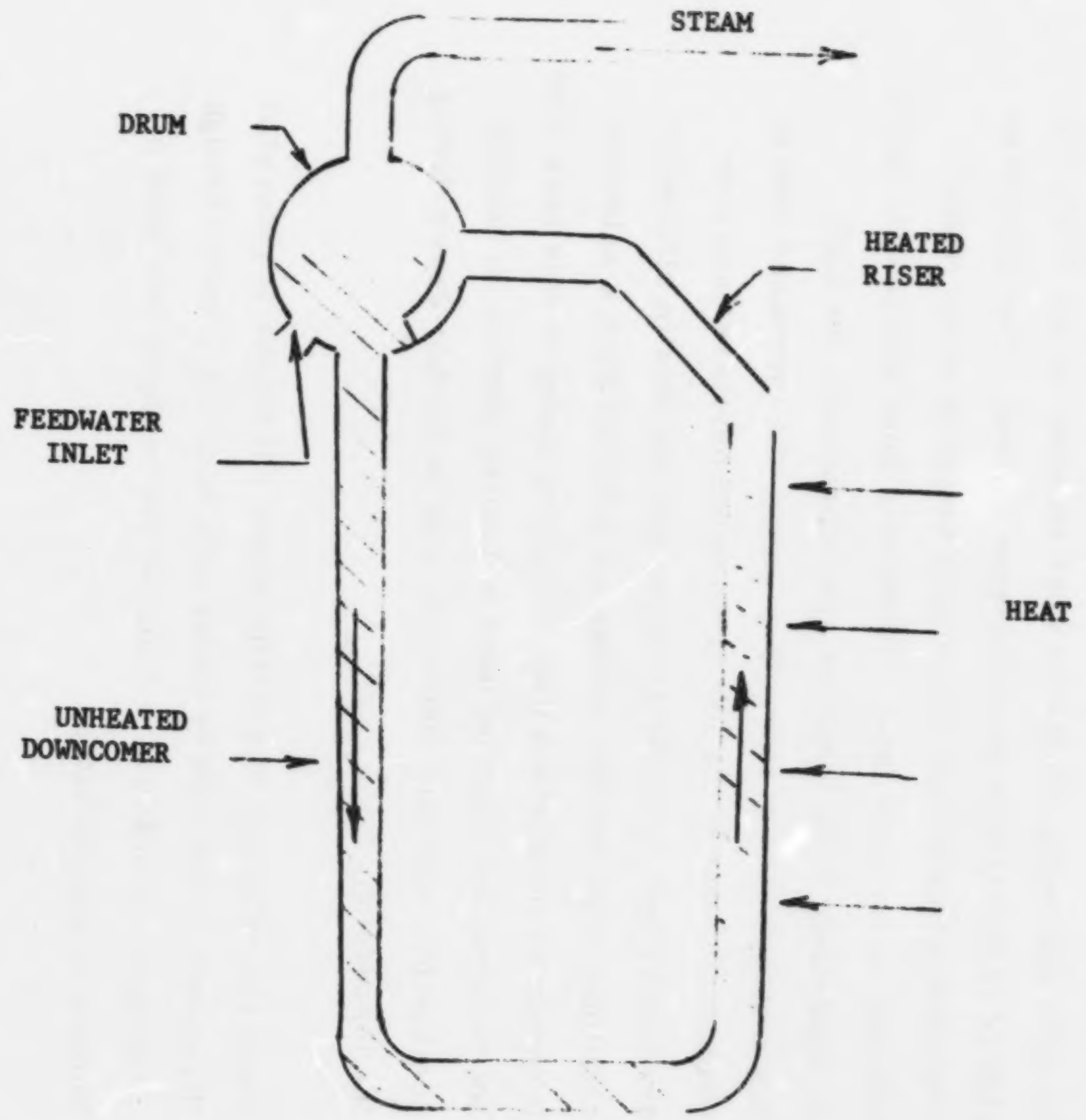
Specific operating conditions were selected on the conservative side of recent trends in utility-type boilers. The capacities required indicated that the boilers would be of the highly efficient water-tube type. Refractory lined combustion zones on separately fired furnaces are impractical: the high maintenance cost of refractory lining, the increased cost of conductance due to the low furnace temperatures and non-productive heat transfer surface, and the loss in efficiency resulting from the high excess air prohibit such a selection. It should be understood that refractory lining in this case does not refer to the material used in limited quantity to control combustion, and this distinction will be further drawn during the discussion.

Since the selection of specific steam conditions is somewhat dependent on the type of boiler selected, i.e., once-through or natural circulation, a brief review of these two types of boilers is appropriate.

a) Natural Circulation Systems

The principle of natural circulation is illustrated in Figure XI-49. Water flows through unheated down-comers to an assembly of tubes or risers. The risers

FIGURE XI-49


STEAM
DRUM
HEATED RISER
FEEDWATER INLET
HEAT
UNHEATED DOWNCOMER

SCHEMATIC DIAGRAM OF A NATURAL CIRCULATION BOILER absorb the heat released by the burners and this absorption causes steam bubbles to form in the water. The formation of steam bubbles reduces the density of the heated water. The difference in density between the water in the downcomers and the mixture of steam bubbles and water in the heated tubes causes the elevated steam-water mixture to flow upward into the drum where steam is separated from the water and flows to the superheater. The remaining water, mixed with incoming feed water, returns through the unheated downcomer to the riser circuit. The amount of water circulating is many times the quantity of steam leaving the drum and depends upon the pressure in the system.

There are certain physical limits to the use of natural circulation. One of these limitations is that at higher pressures, about 2, 800 psi, the forces that produce natural circulation decrease rapidly. As a result, separation of steam and water in a drum becomes more difficult to the extent that economical design of a natural circulation boiler is impossible. Also, natural circulation is limited by capacity restrictions: at higher circulation rates a single drum becomes unwieldy, and, for two or more drums in series, uniform circulation becomes difficult.

b) Once-Through System

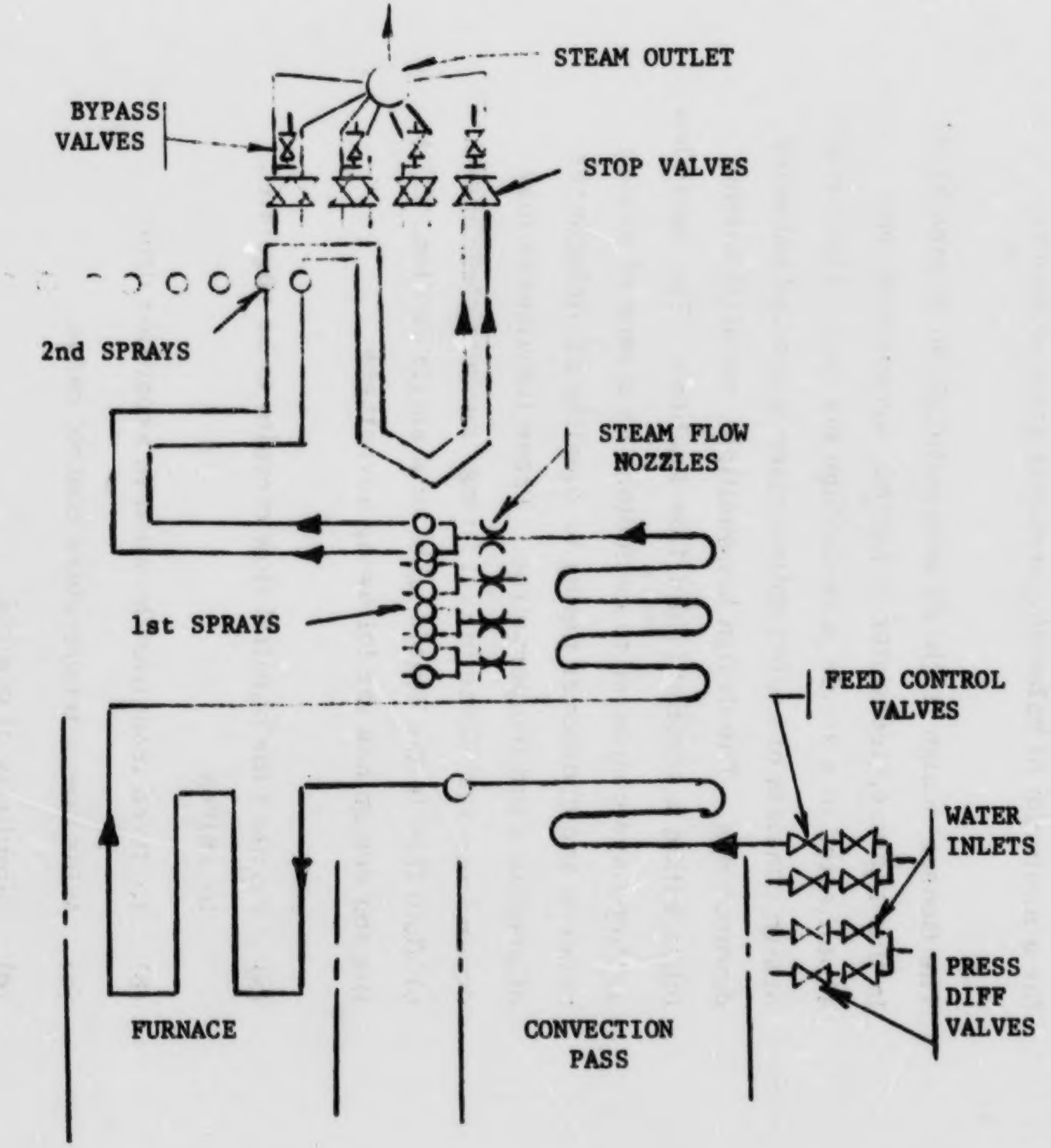
The once-through steam generator is basically a series of tubes, connected to serve as a single long circuit, formed by the furnace enclosure and part of the convection passes to the steam generator. Feedwater is pumped into one end of the tube circuit and is converted into steam by the heat liberated from the burning fuel. The steam, which can be further heated to a desired degree of superheat, leaves from the end of the tube circuit. The boiler feed water pumps force the water through the circuit.

The design of a once-through steam generator is controlled by two factors, the firing rate and the feedwater flow. This system is more flexible than the natural circulation method since it can maintain high steam temperatures over a wide range of operations and can be used at super-critical as well as subcritical pressure levels.

The two basic types of once-through steam generator designs are the Sulzer and the Benson. Figure XI-50 illustrates the Sulzer design which consists of multiple parallel circuits, each with its own water flow regulated for variations in the heat absorption rate of the circuit. In each circuit, the transition from water to steam is controlled so that it will occur at a fixed point. Sub-critical units have a separator and blow-down system which removes the moisture at that point in each circuit where the fluid is 95% steam.

The Sulzer system has inherent disadvantages due to the complexity of the design, which requires a multiplicity of parallel controls, all capable of precise adjustment, for successful operation. Also, designing the parallel passes

FIGURE XI-50


STEAM OUTLET
BYPASS VALVES
STOP VALVES
2nd SPRAYS
STEAM FLOW NOZZLES
1st SPRAYS
FEED CONTROL VALVES
WATER INLETS
PRESS DIFF VALVES
FURNACE
CONVECTION PASS

SCHEMATIC DIAGRAM OF A SULZER ONCE-THRU STEAM GENERATOR for a minimum of balancing presents great difficulty.

The Benson design is shown schematically in Figure XI-51 In this scheme, feedwater is heated, evaporated, and superheated in a single pass through the unit. The circuit design consists of heated upflow riser tubes and unheated downcomers. The design has multiple, parallel heating tubes within a series of fluid-flow sections. The fluid-flow sections are connected to each other by means of mixing headers and crossover piping to equalize all imbalances of pressure and temperatures. These imbalances may occur from variations in fuel firing, surface cleanliness, or fluid flow in the heated tubes of a single section. The Benson design has the following advantages:

(a) No need for parallel flow circuits to be regulated by valves.

(b) No fixed transition location in separator drum.

(c) Wide steam temperature control range.

(d) Simplicity of control.

Figures XI-52 and -53 illustrate the basic control and startup systems for a once-through steam generator.

c) Engineering Comparison

The natural circulation and once-through systems have most of their basic components in common. These include:

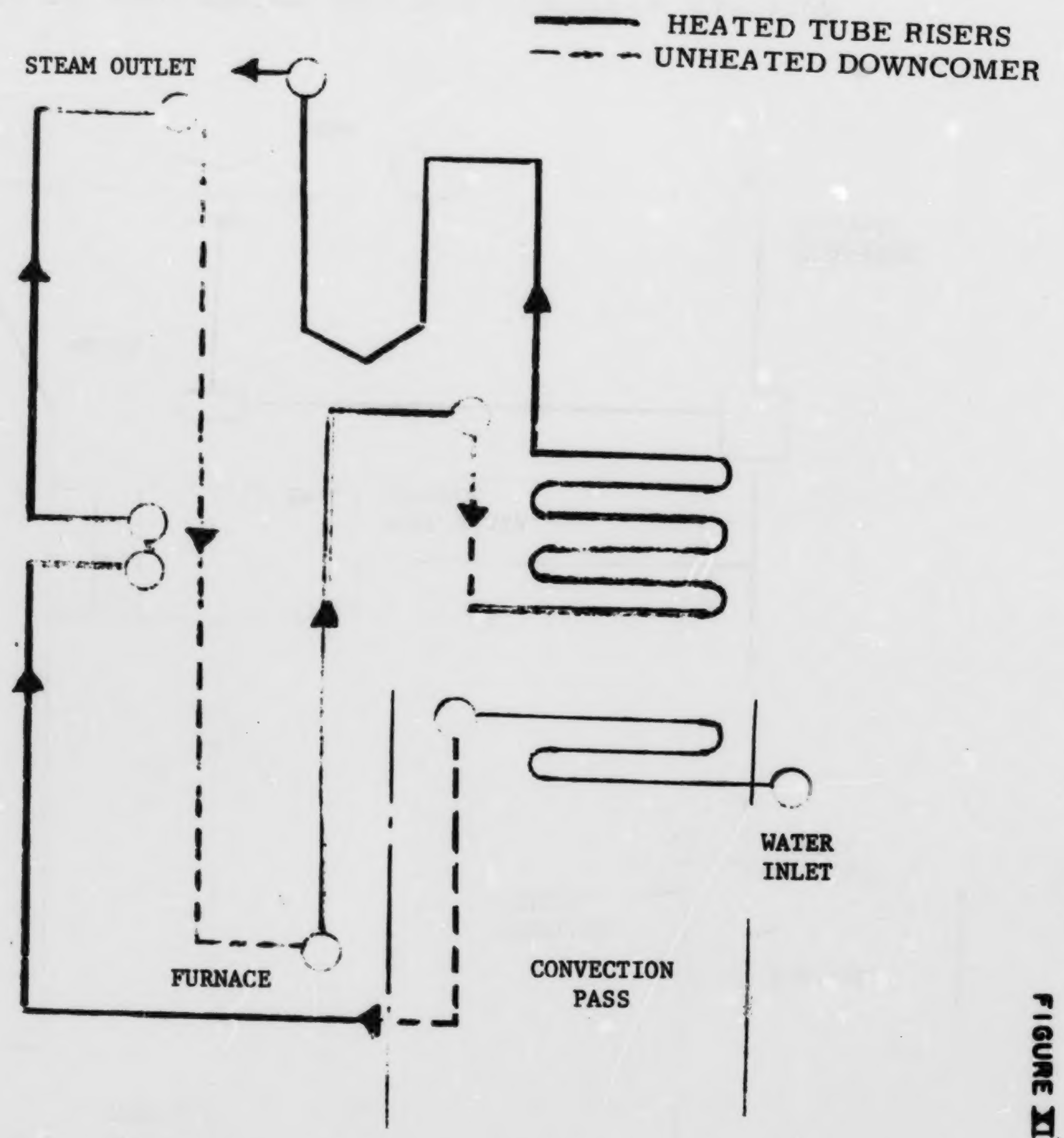
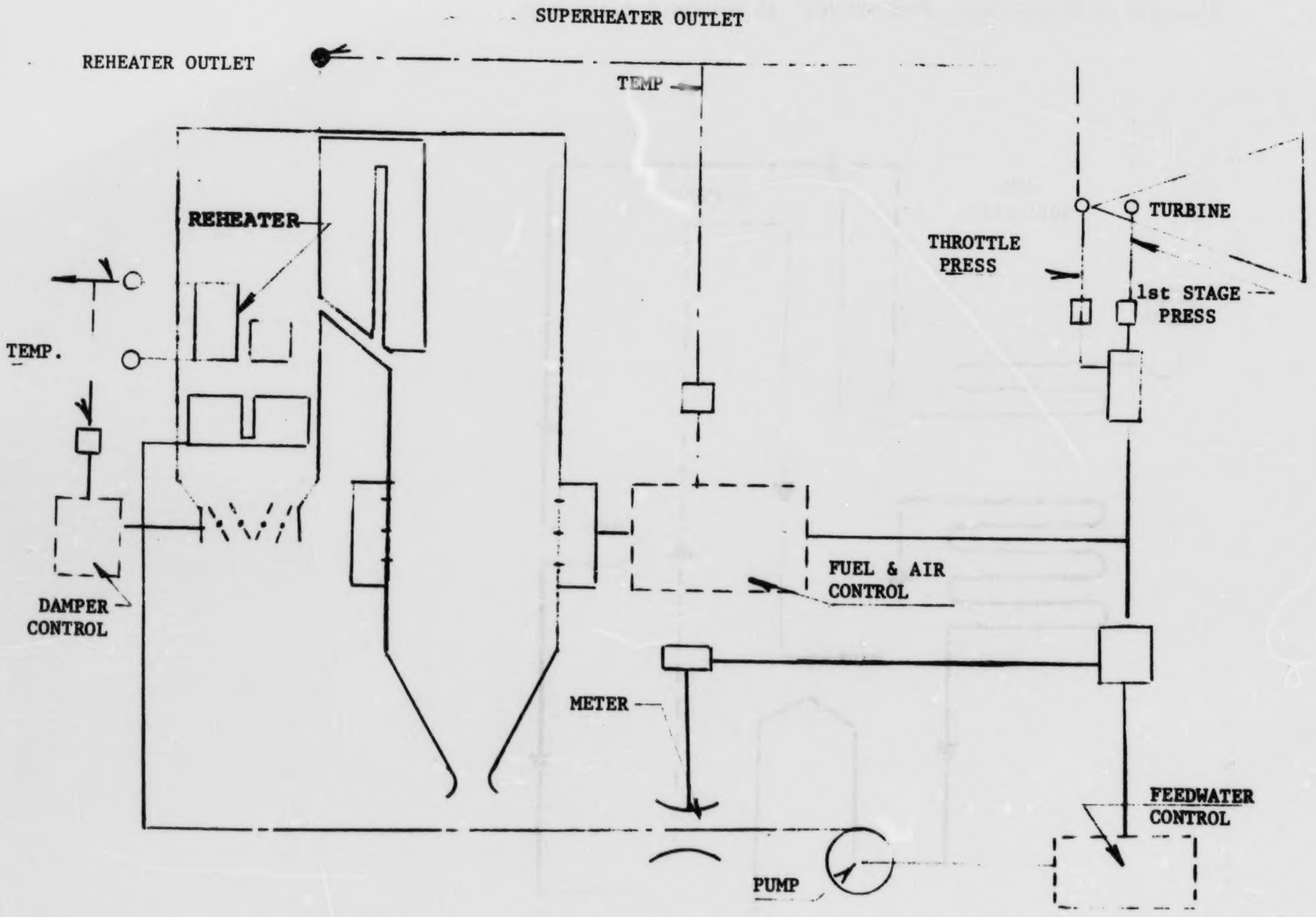

HEATED TUBE RISERS
UNHEATED DOWNCOMER
STEAM OUTLET
WATER INLET
FURNACE
CONVECTION PASS

FIGURE XI-51

SCHEMATIC DIAGRAM OF BENSON ONCE-THRU STEAM GENERATOR


SUPERHEATER OUTLET
REHEATER OUTLET
TEMP
REHEATER
TEMP.
DAMPER CONTROL
TURBINE
THROTTLE PRESS
1st STAGE PRESS
FUEL & AIR CONTROL
METER
PUMP
FEEDWATER CONTROL

SCHEMATIC DIAGRAM OF THE BASIC CONTROL ON A ONCE-THRU STEAM GENERATOR

FIGURE XI - 52

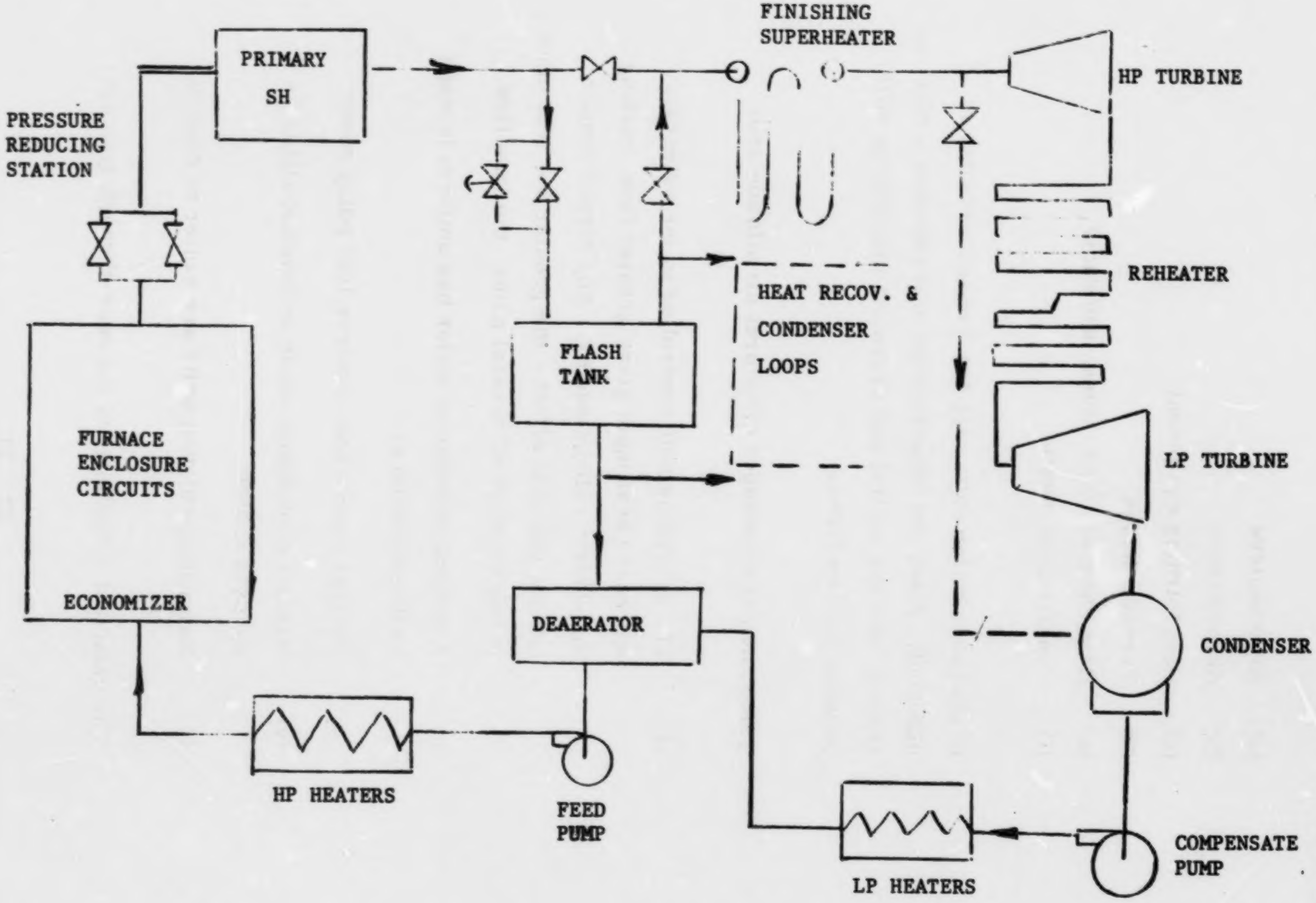

PRIMARY SH
PRESSURE REDUCING STATION
FURNACE ENCLOSURE CIRCUITS
ECONOMIZER
FLASH TANK
FINISHING SUPERHEATER
HEAT RECOV. & CONDENSER LOOPS
HP TURBINE
REHEATER
LP TURBINE
DEAERATOR
CONDENSER
HP HEATERS
FEED PUMP
LP HEATERS
COMPENSATE PUMP

FIGURE XI - 53

SCHEMATIC DIAGRAM OF THE START UP SYSTEM FOR A ONCE-THRU STEAM GENERATOR

(a) Superheaters
(b) Economizers
(c) Fuel Burning equipment
(d) Furnace design
(e) Heat recovery fans, flues, and ducts
(f) Construction details

In the basic boiler unit, only the furnace circuitry is different. Also, the once-through unit requires a start-up system, and the control and operating procedures differ between the two types.

The principal advantages of natural circulation are:

i) The system is self-controlled to the extent that increased heat input gives greater flow, making the system self-balancing. Any forced system has the opposite effect - the greater the heat input in one or more of several paths, the less flow.

ii) A natural circulation boiler has uniform furnace wall temperatures.

iii) Natural circulation requires less pump power.

iv) Natural circulation needs no demineralizer or by-pass system.

v) Natural circulation units are easier to control.

The principal advantages of the once-through type are:

i) Elimination of drums, which becomes a problem at higher capacities.

ii) Operation at much higher cycle pressures and temperatures.

Since the natural circulation boiler is generally associated with a liberal furnace size it would be the likely choice for firing a pyritic-rich HSC Fuel which requires long residence time, lower release rates, and minimum flame impingement on tube walls. By selecting a natural circulation boiler, the operating conditions are limited to subcritical steam pressures. A single reheat cycle may be used to give a high boiler efficiency comparable to conventional plants of similar sizes. The 500 MW capacity requires a steam flow of 3, 500, 000 pounds per hour. Conditions for this unit were established in keeping with the most highly developed and reliable modern practice in operating units purchased by electric utility companies. See Table V-1 in Volume One.

The steam generating conditions are shown in Table XI-12.

The design conditions for the 500 MW unit were chosen primarily on scale-up considerations and are not typical for 50 MW size units. A straight superheat cycle was chosen for the latter with an operating pressure of 1, 450 psig and temperature of 1, 000° F. The feedwater temperature

TABLE XI-12

Steam Generating Conditions for the Various Boiler Designs

Conceptual Design (500 MW)

Capacity	500 MW
Steam Flow	3,500,000 lb/hr
Fuel - FeS_2 Concentration	26.4%
Steam Pressure	2500 psig
Steam Temperature	1005°F
Reheat Pressure In	580 psig
Temperature In	629°F
Pressure Out	555 psig
Temperature Out	1005°F
Feedwater	480°F
Flue Gas Exit-Air Heater	500°F

Prototype (50 MW)

Capacity	50 MW
Steam Flow	500,000 lb/hr
Fuel - FeS_2 Concentration	26.4%
Steam Pressure	1450 psig
Steam Temperature	1000°F
Reheat	None
Feedwater	430°F
Flue Gas Exit-Air Heater	500°F

Conceptual Design (50 MW)

Capacity	50 MW
Steam Flow	500,000 lb/hr
Fuel - FeS_2 Concentration	77%
Steam Pressure	900 psig
Steam Temperature	825°F
Reheat	None
Feedwater	300°
Flue Gas Exit-Air Heater	500°F

TABLE XI-13

EXPECTED HSC FUEL-FIRED
COMBUSTOR PERFORMANCE

Composition of Fuel - Combustibles Only:					
% FeS_2	0	25	50	75	100
% Coal	100	75	50	25	0
S/C Ratio	0	0.18	0.53	1.6	∞
Heat Losses, %					
Dry Flue Gas	9.9	10.2	10.7	11.8	14.5
Hydrogen + Water in the fuel	4.3	4.2	4.0	3.6	2.5
Moisture in the Air	.23	.23	.24	.26	.32
Unburned Carbon	.1	.31	.66	1.29	3.2
Radiation	.38	.38	.38	.38	.38
Unaccounted for	1.5	1.5	1.5	1.5	1.5
Total	16.4	16.8	17.5	18.8	22.4
Boiler Efficiency %	83.6	83.1	82.5	81.2	77.6
Flue Gas/Fuel Weight Ratio	13.7	11.4	9.0	6.7	4.3
Air/Fuel Weight Ratio	12.7	10.5	8.3	6.1	3.9
MBTU per POUND, ca.	14	11.3	8.5	5.8	3.0

Moisture in actual HSC fuel 6%.

Non-pyritic ash in actual HSC Fuel 20%.

Combustion in 25% excess air.

Humidity of air 60% relative humidity at 80° F.

was set at 430° F. The steam flow required is 500,000 lb/hr.

The 500,000 lb/hr industrial boiler operates on the least severe cycle conditions and its superheat requirements are modest. The boiler outlet pressure is set at 900 psig and 825° F. Feedwater temperature is usually fixed by the deaerator operating temperature which is about 300° F. In power plants, the situation is a slightly different one in that the system is closed and the return steam is condensed at near atmospheric temperature. To improve cycle efficiency the Rankine cycle uses bleed steam to feedwater heaters to bring the temperature of the water at the boiler inlet up to about 450° F. Thus, less preheat service is required in the boiler itself.

All three units have lower efficiencies than conventional units due to the high flue gas exit temperature required to avoid cold-end corrosion. The dewpoint of the flue gas at the high level of sulfur concentration is about 400° F. To insure added protection an exit temperature of about 500° F was selected, introducing thermal loss somewhat higher than in the dry gas of conventional plants.

High sulfur combustors also have a higher "carbon" loss from uncombusted HSC Fuel in the fly ash due to the higher ash loading. Since there are no quantitative data for pyritic blends, a value for carbon loss had to be assumed.

The totals of the boiler losses for all cases are tabulated at various pyrite concentrations in Table XI-13. With the higher losses there is a correspondingly lower efficiency which is also taken into consideration.

5.2 Engineering Details

5.2.1 Superheater steam control

Control of the final superheater temperature is usually achieved in any one of several ways. These include:

a) Spray control
b) Gas recirculation control
c) Tilting burners
d) Combination radiant and convection superheat control

The various systems are illustrated in Figure XI-54.

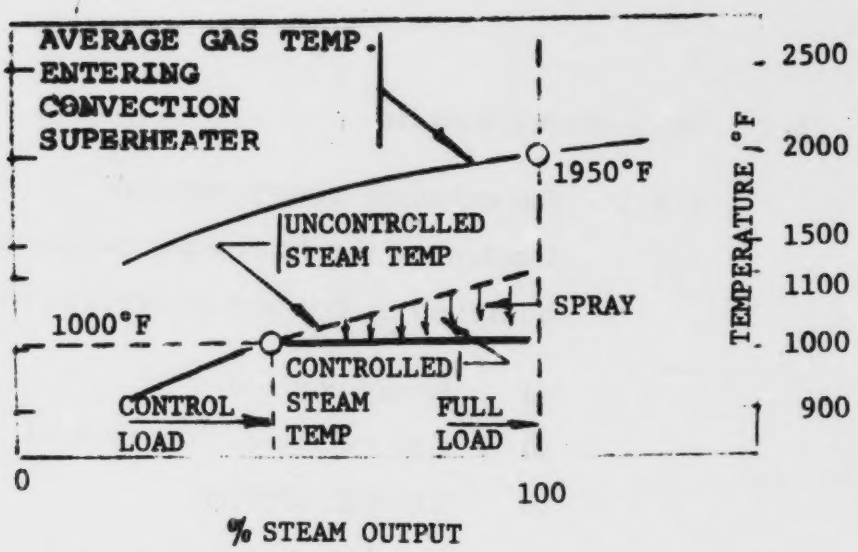
In a 1,500 psi, 1,000° F. steam generating unit, the superheater heat duty is moderate. The superheater is designed for full steam temperature at the control load. At this point, the required furnace temperature is low and sufficient heating surface is installed to obtain the design steam temperature.

Above the control load, the steam temperature will be too high unless it is moderated by spraying water between superheater sections. Note that the gas temperature entering the convection superheater is satisfactory to prevent slagging at all loads. At the highest heat load the temperature need not be more than 1,950° F. At higher steam pressures, spray control is inappropriate since 51% of the total heat absorption is required by the superheater and reheater. At this condition, the gas temperature to the superheater

FIGURE XI-54

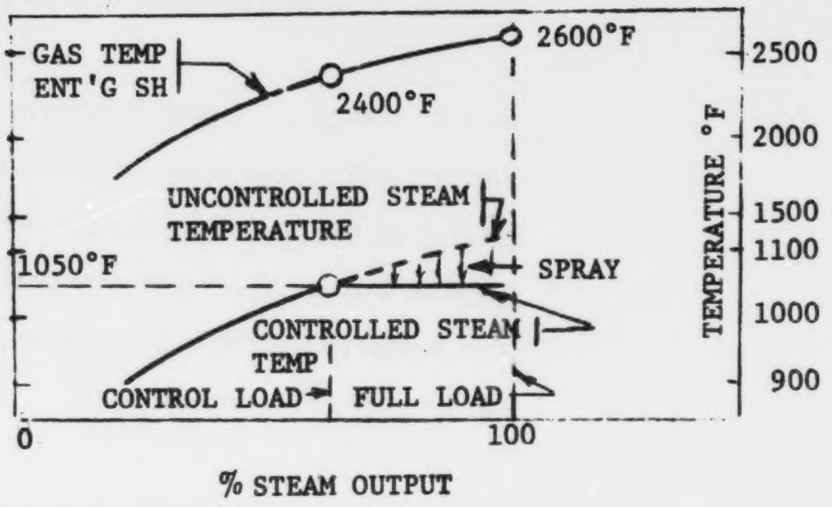
1500 PSI - 1000F CYCLE:

SPRAY CONTROL



2400 PSI - 1050F-1000F CYCLE:

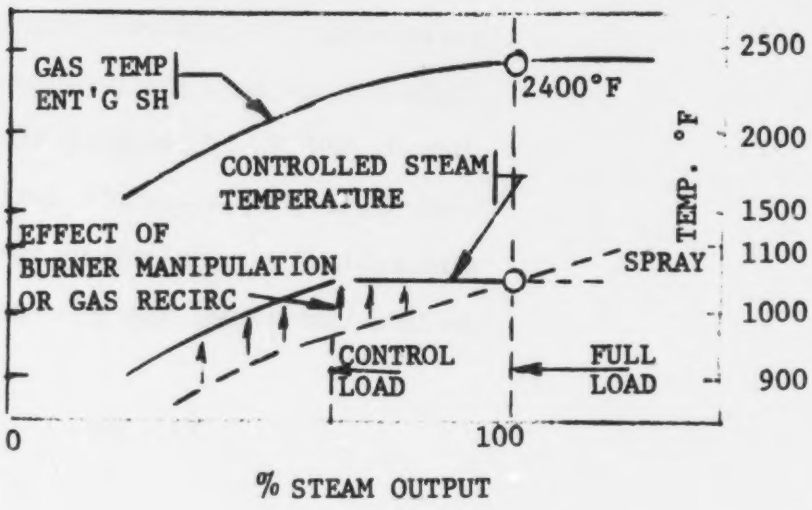
SPRAY CONTROL



2400 PSI - 1050F-1000F CYCLE:

BURNER OR

GAS RECIRCULATION CONTROL



must be 2, 400° F at the control loads to provide enough heat for the gas to reach full superheat and reheat levels; however, at this temperature slag will form, and at full load the gas temperature increases to 2, 600° F, and this only worsens the slagging situation even more.

These high gas temperatures usually cannot be tolerated. The tubes in the convection banks must be widely spaced to minimize fouling and slagging characteristics. It is commonly accepted that an increase in boiler maintenance will result from slagging at high furnace exit temperature. High gas temperatures also produce high metal temperatures leading to oxidation and corrosion of the tube metal.

This situation can be improved somewhat by designing the unit for full steam temperatures at full load only, and then increasing the temperature at the reduced loads.

This can be accomplished through reduction of furnace effectiveness by manipulating the burners, thus increasing the gas temperatures to the convection surfaces. It can also be accomplished through gas recirculation; that is, re-introducing gas into the furnace, to decrease the effectiveness of the furnace walls and to increase the heat transfer of the convection surfaces. A unit that is designed in this manner still requires a rather high gas temperature entering the superheater at full load in order to prevent slag formation.

Another potential solution exists given the facts that the radiant superheater has a falling temperature characteristic (i.e., the steam temperature decreases as the steam flow increases), while the convection superheater has a rising steam characteristic (i.e., gas temperature and mass velocity increase with steam flow.) By combining the two effects, a relatively flat, uncontrolled steam temperature over a wide range of loads is produced. High furnace exit gas temperatures are not needed, nor excessive desuperheating, gas recirculation, or manipulation of burners.

5.2.2 Reheat temperature control

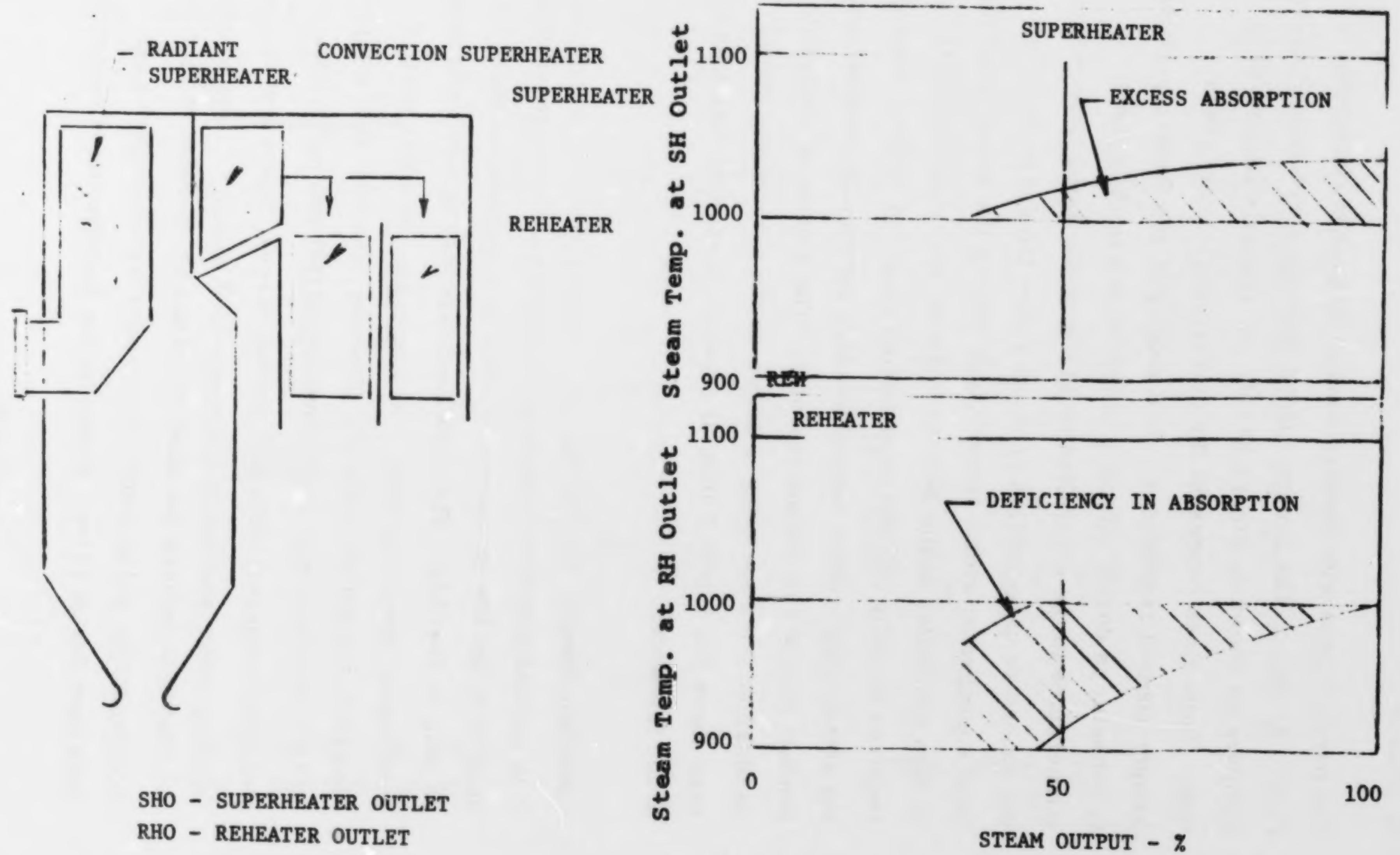
Reheat temperature may be controlled by:

1) Gas Recirculation
2) Parallel pass without damper control.
3) Parallel pass with proportioning dampers.

Reheat control with gas recirculation requires that a portion of the high temperature gases are returned to the upstream side of the reheater. The obvious disadvantage of this system is that it requires a fan operating on high temperature gases, necessitating additional maintenance and power. When the furnace temperature rises considerably, recirculation systems may require supplementary spray controls.

The parallel pass without damper control method is illustrated in Figure XI-55. Both superheater and reheater are designed for full temperature at full load with almost equal gas flow to the superheater and reheater passes. As indicated in this figure, the superheater temperature will have a combination radiant-convection characteristic, whereas, the reheater will have an all convection characteristic. Below top load, the superheater has excess absorption for full temperature.

FIGURE XI-55


RADIANT SUPERHEATER
CONVECTION SUPERHEATER
SUPERHEATER
REHEATER
SHO - SUPERHEATER OUTLET
RHO - REHEATER OUTLET
Steam Temp. at SH Outlet
SUPERHEATER
EXCESS ABSORPTION
1100
1000
900
REH
REHEATER
Steam Temp. at RH Outlet
DEFICIENCY IN ABSORPTION
1100
1000
900
0
50
100
STEAM OUTPUT - %

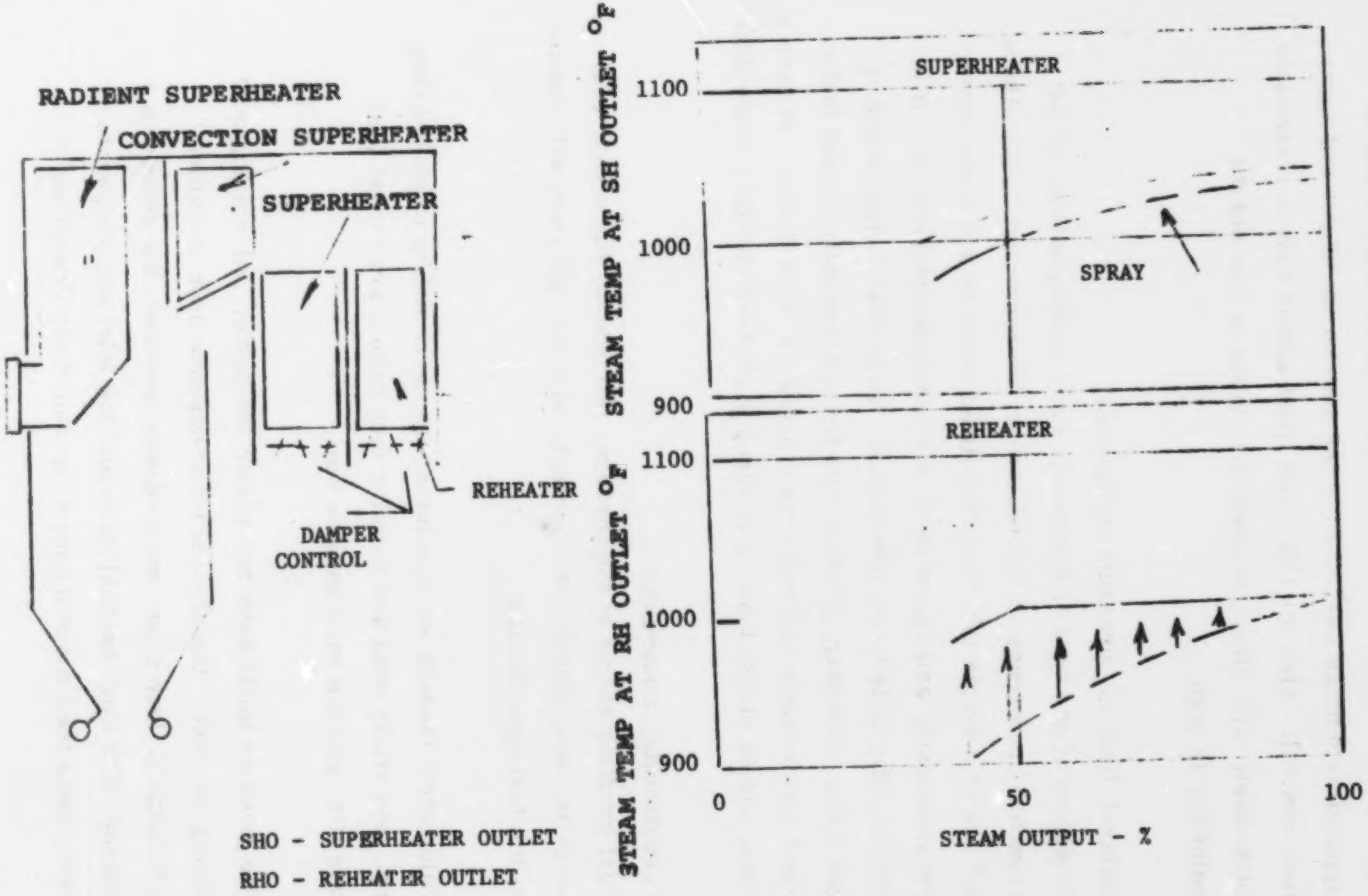
SCHEMATIC DIAGRAM OF A PARALLEL PASS SYSTEM WITHOUT DAMPER CONTROL

The parallel pass with damper control method is illustrated in Figure XI-56. The broken curves indicate performance without dampers as shown in Figure XI-55, or with all dampers fully open. Solid lines represent the performance under reheat damper control regulations. The biasing of gas from superheater to reheater is doubly effective in that it raises the reheat temperature to the controlled level and at the same time reduces the excessive uncontrolled primary steam temperature. The final superheater steam temperature exiting the steam generator is then controlled to the desired value by spraying feedwater, as required directly into the superheated steam as it flows through the steam temperature control headers between the radiant and pendant sections of the superheater. The amount of control to be obtained from spraying is shown as the narrow horizontal area above the 1, 000° F line, it usually represents less than 2% of the feedwater.

5.2.3 Operating Rate

It is normal practice to operate conventional steam generating units with the lowest operating costs on a continuous basis for as long as feasible. The peak loads are met by auxiliary units with higher operating costs. In this case, the economics of operation are not yet defined. However, the best course appears to be a base load operation considering that two products are produced subject to different market forces, that a low cost fuel is being used, and that fuel storage is difficult. There is now no reason to believe the plant could not be operated at less than full capacity, and no performance data were developed for less than design rates. Based on the distribution of superheater

FIGURE XI-56


RADIENT SUPERHEATER
CONVECTION SUPERHEATER
SUPERHEATER
REHEATER
DAMPER CONTROL
SUPERHEATER
SPRAY
REHEATER
STEAM TEMP AT SH OUTLET °F
STEAM TEMP AT RH OUTLET °F
1100
1000
900
1100
1000
900
0
50
100
STEAM OUTPUT - %
SHO - SUPERHEATER OUTLET
RHO - REHEATER OUTLET

SCHEMATIC DIAGRAM OF A PARALLEL PASS SYSTEM WITH DAMPER CONTROL and reheater surface, the turn-down characteristics should approximate those described in the section on reheat and superheat control. Also the HSC Fuel fired should have a reasonable turn-down ratio since its reactivity index is low and the volatility is high.

5.2.4 Natural draft vs. pressurized furnace

Selection of one type or another is very much a matter of the personal preference of the customer. Pressurized firing allows the use of a single fan, has simplified controls and lower power requirements, and operates on low temperature air only. It is readily adaptable to the new furnace wall construction which is gas tight. However, pressurized firing frequently causes higher plant maintenance and requires a pressure-tight boiler. In such a case, air or steam lancing or furnace probing becomes more difficult.

5.2.5 Fuel Handling Equipment

Fuel handling starts at the feeders, followed by the mills, coal conduits, and, finally, the burners; only the last item will depend on the fuel specification.

Volumetric feeders were selected for their ability to handle fine, wet, and sticky coal and because they have a low initial cost, long life, and low maintenance cost.

The grinding mills have two major functions: pulverizing and drying the fuel. The first service depends upon moisture, grindability, feed size, and fineness required; the second is a function of the air-to-coal ratio and the inlet air temperature. Based upon the expected operating conditions described in

Section XI-4, there is only one mill that appears to fit the situation in all cases, that is, the ball-tube mill. It is capable of handling an abrasive, hard material with a low grindability, which necessarily must be done at the expense of more energy input.

The ball and tube mill consists of a rotating drum charged with steel balls and coal as shown in Figure XI-57. Heated air enters the mill through the central pipes and carries the pulverized coal through the annular opening to the classifier. Oversize rejects drop from the classifier to the spiral flights, where they mix with the raw-coal feed. Since the rejects are practically free of moisture and preheated above ambient temperatures (180° F) they tend to reduce the surface moisture of the raw coal; next they are pulverized by impact and attrition brought about by the cascading action of the balls and coal.

Feed control is automatic so that a constant level is maintained in the mill regardless of the output. A relevant feature is the large reserve supply of fuel maintained in the mill which is available to meet fluctuation in demand or alleviate the effects of coal flow interruption due to blockages in bunker or spouts.

The ball mill is pressurized and fed with hot air preheated to 100° F in the air preheater. The process air, stripped from the main stream of preheated air, is almost instantly cooled on contact with the moist coal. Together, the air and coal mixture pass out through the classifiers, where over-size material is

FIGURE XI-57

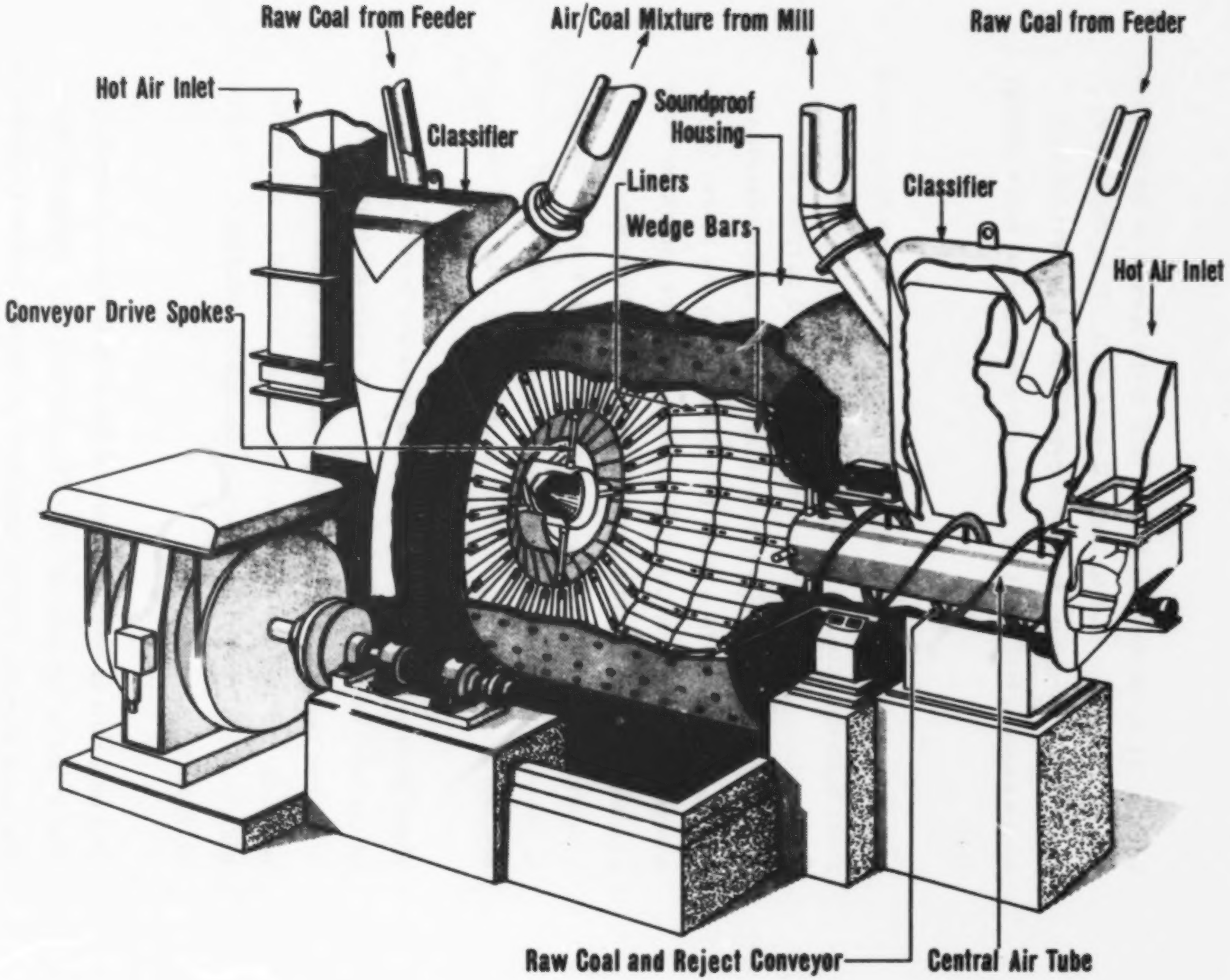

Raw Coal from Feeder
Air/Coal Mixture from Mill
Raw Coal from Feeder
Hot Air Inlet
Classifier
Soundproof Housing
Liners
Wedge Bars
Classifier
Hot Air Inlet
Conveyor Drive Spokes
Raw Coal and Reject Conveyor
Central Air Tube

DIAGRAM OF A BALL MILL AND CLASSIFIER

selectively returned to the mill by centrifugal force, and transported through circular conduits to the burners for firing. Velocities in the conduits are maintained between 50 and 90 feet per second, depending on orientation, to avoid plugging and abrasion. Tempering air by-passes the air preheater and is used at off-load conditions or during such time when moisture variations exist to control the temperature of the air to the mills. The overall air distribution is schematically illustrated in Figure XI-58.

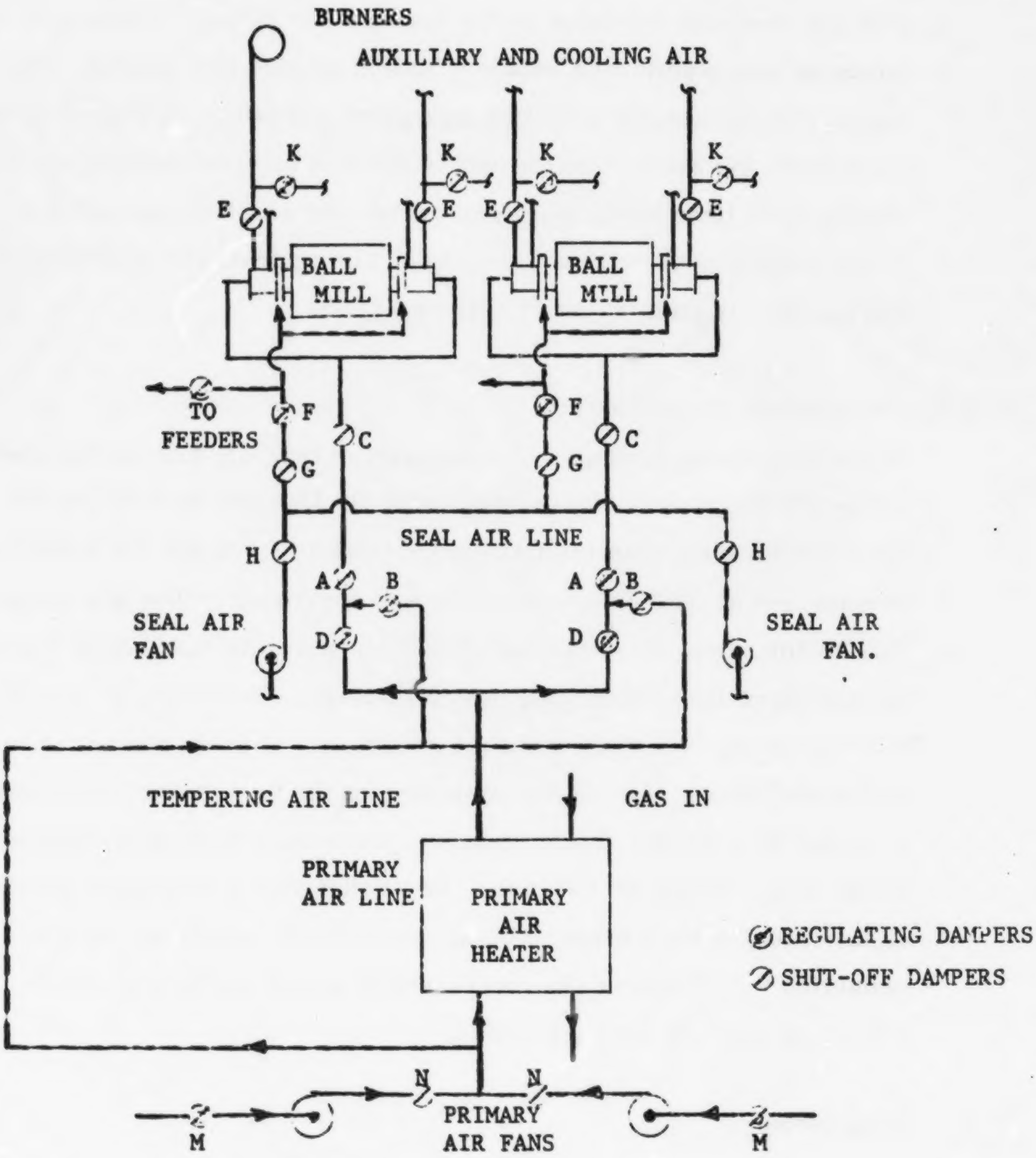
5.2.6 Combustion air preheater

The Ljungstrom continuous regenerative type air heater has been proposed to recover waste heat from the flue gas by heating the combustion air. Gas temperatures emitted from the air heater are maintained at 500° F to avoid cold end corrosion. The gas temperature to the air heater was set at 900° F, which is just below the temperature level requiring special design. However, it is sufficiently high to dry up fuel containing 6% moisture. It is important to insure complete evaporation of any moisture in the fuel prior to combustion in order to maintain flame stability under such high inert concentrations, i.e., about 50-60% ash. Any reduction in moisture level, at the flue gas temperature being considered, would warrant a reduction in preheater size and installation of additional steam generator heat recovery surface.

5.2.7 Soot blowers

The behavior of the ash from a pyrite-rich HSC Fuel with low non-pyritic ash concentration is uncertain since no actual field experience exists. Therefore, for design purposes, it was assumed that the ash would be typical of a high ash coal,

FIGURE XI - 58


BURNERS
AUXILIARY AND COOLING AIR
K
K
K
K
E
E
E
E
BALL MILL
BALL MILL
TO FEEDERS
F
F
C
C
G
G
SEAL AIR LINE
H
H
A
B
A
B
SEAL AIR FAN
D
D
SEAL AIR FAN.
TEMPERING AIR LINE
GAS IN
PRIMARY AIR LINE
PRIMARY AIR HEATER
REGULATING DAMPERS
SHUT-OFF DAMPERS
N
N
M
PRIMARY AIR FANS
M

SCHEMATIC DISTRIBUTION OF AIR

causing fouling that could be readily handled by conventional soot blowing equipment.

It is proposed that the 500 MW unit be equipped with automatic, sequential, steam blowing, electric motor driven, electrically controlled soot blowers. Twenty-eight Model 1K-525 long retractable blowers with approximate coverage of 40 feet will be installed on both sides of the convection pass. Forty Model 1R3 short retractable wall blowers will be installed throughout the furnace. The soot blowers will be controlled with a Drammond Selectronic, all silicon, solid state, soot blower control panel, insert type, with self-contained enclosure for operation of the boiler cleaning systems from the control room. The pressure reducing stations will include a 1-1/2" Fisher Type 667-2500 psig reducing valve and accessories. They will operate on 2, 500 psi steam at 450° F.

The 500, 000 lb/hr industrial boiler will be equipped with similar equipment less elaborate controls. In this case, the soot blowers will include eight Model 1K-525 long retractable blowers with approximate coverage of 22 feet. Five Model 1R3 will be installed as wall blowers in the furnace. The blowing medium source is 850 psi steam at 750° F; no reducing steam is required.

The 50 MW unit will be equipped with eight Model 1K-525 long retractable blowers with approximate coverage of 22 feet. As in the 500, 000 lb/hr unit, these will be installed in the convection side and enter from one side only. Fourteen Model 1R3 short retractable blowers will be distributed along the furnace walls. A 2" Fisher Type 667-1500 psig reducing valve will be required to provide suitable steam to the blowers. The blowing medium source is 1, 500 psi, 800° F steam.

5.2.8 Mechanical cleaning equipment

Centrifugal type separators will be installed after the air preheaters to remove a large quantity of particulate matter before exhausting to the sulfur recovery system. Mechanical dust collectors as illustrated in Figure XI-59 are proposed. They are designed to have an efficiency of about 82% for the particle distribution described below:

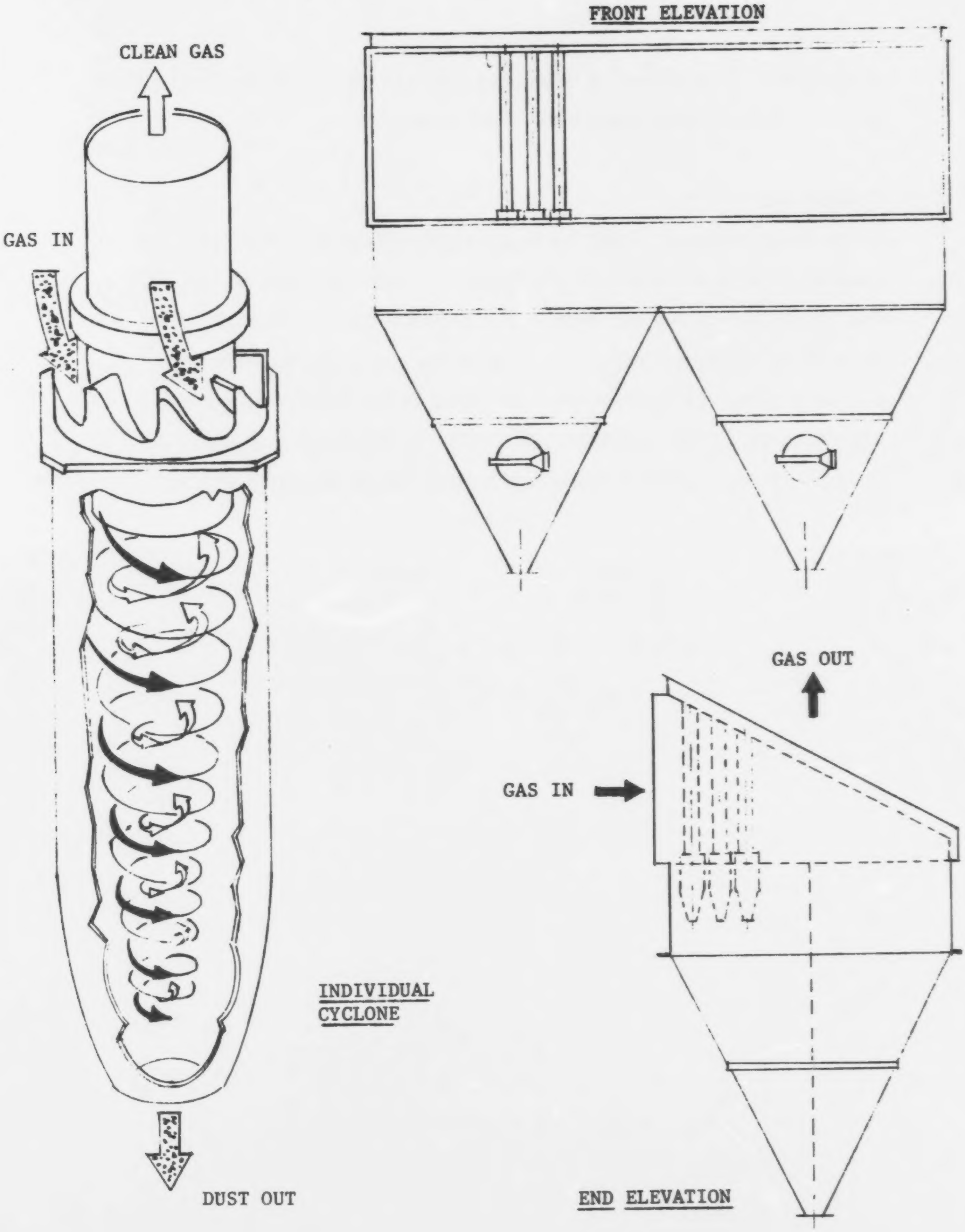
TABLE XI-14

Physical Characteristics of Ash for Various Particle Sizes

Particle Size	Average Particle Size	% in Gas Stream
+60 Microns	60 Microns	10
-60 +40	50	10
-40 +30	35	4
-30 +20	25	11
-20 +15	17.5	10
-15 +10	12.5	15
-10 +7.5	8.75	8
-7.5	3.75	32
		100%

Although the coal-pyrite mixture was finely ground, 90% through 200 mesh, it cannot be assumed that small ash particles exist in the furnace. Little is known about agglomeration and no correlation exists for predicting ash size from

FIGURE XI-59


FRONT ELEVATION
CLEAN GAS
GAS IN
GAS OUT
GAS IN
INDIVIDUAL CYCLONE
DUST OUT
END ELEVATION

MECHANICAL DUST COLLECTOR

coal fines. Therefore, a standard ash size distribution was used from a conventional pulverized coal plant.

5.2.9 Excess air

To prevent corrosion and fouling as the result of reducing conditions in the boiler, the excess air required was set at 25% and provision in the fan capacity was made for up to 50%. The formation of oxides rather than sulfides is dependent upon the proper amount of excess air. Burning of pyrites is apparently sensitive to the values selected. This is one factor that should be investigated in the laboratory before constructing a boiler to operate on the HSC Fuels proposed.

5.3 50 MW Prototype

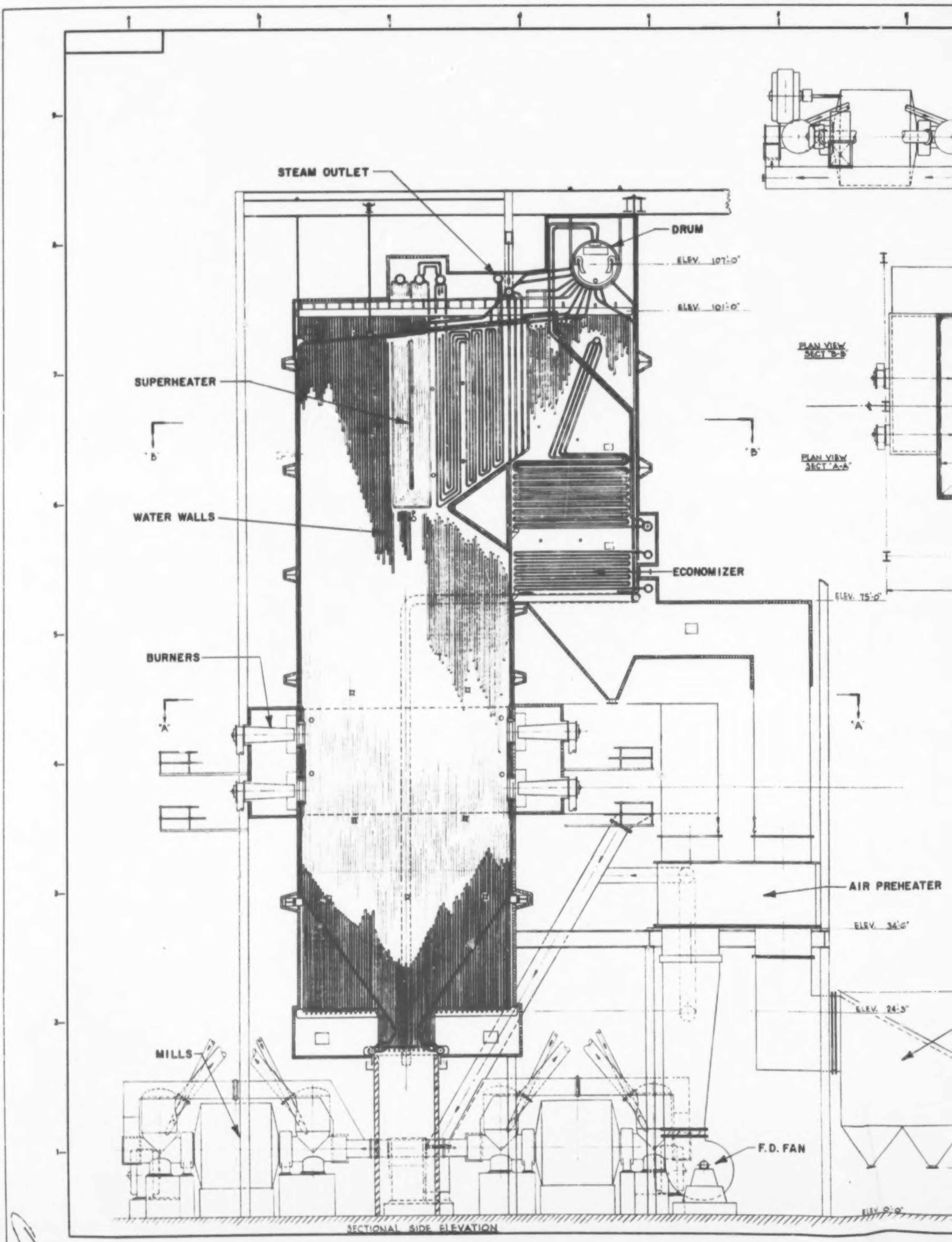
The 50 MW prototype unit illustrated in Figure XI-60 operates on Fuel C as shown in Part XI-2. The unit is a horizontally fired, natural circulation, straight superheat boiler using intervane burners served by ball and tube mills. The unit is pressurized and air is circulated throughout by a single forced draft fan providing atmospheric pressure at the mechanical dust collector exit. Only one fan is used in this unit since it is prototypal and experimental in nature. In more conventional practice, two fans each capable of 2/3 capacity would be used resulting in a very small increase in cost. Such a change can be made without any modifications.

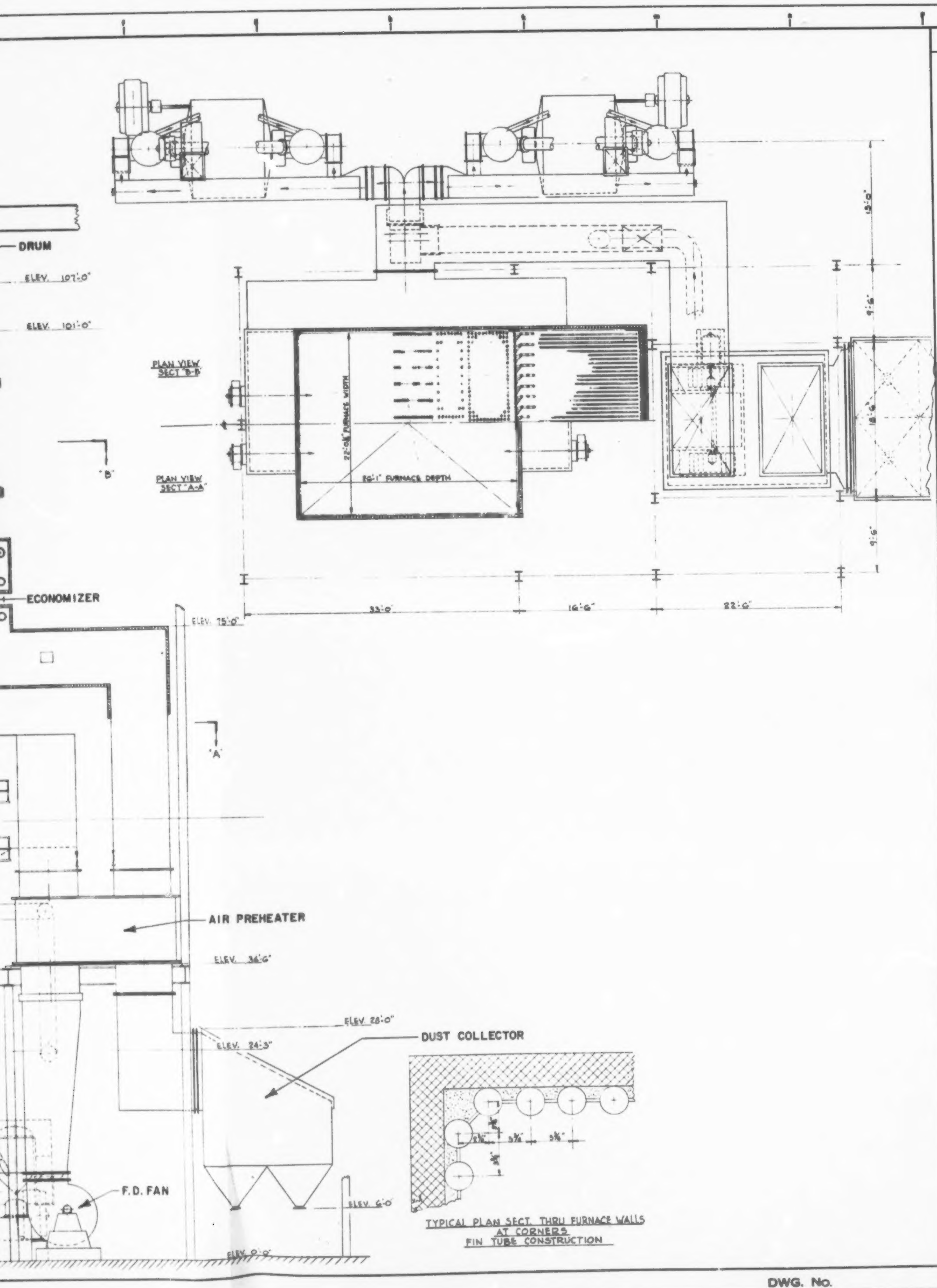
In the straight superheat cycle, 25% of the heat exchanged is used for superheating, 45% for evaporation, and about 16% for preheating of the feedwater. Approximately 17% leaves the stack as a loss. To avoid fouling of the tube bundles, the furnace exit temperature must be kept below 2,000° F. This means a portion of the feedwater heating or superheating service must be done in the furnace where the heat is primarily transferred by radiation. Generally, superheater tubes, when suspended in the furnace on 18 inch centers, have a sufficient mean radiant beam length so that their surface can be considered radiant heat transfer surface. By properly proportioning the superheater surface between convection section and radiant section, the fouling requirements can be met concurrently and the superheat characteristics can be flattened out over a wide range of temperatures. This procedure has been followed in the 50 MW unit.

This furnace is entirely water cooled by finned tubes, and of monowall construction making the furnace air tight. Evaporation and some feedwater heating takes place in these tubes. The tubes are 3" O.D. on 3-3/4" centers. Feedwater heating takes place in the economizer section just before the flue gases leave the steam generator and enter the air heater. The economizer tubes are bare tube elements consisting of single loops of 2" O.D. tubes on 4" vertical centers and 6" transverse centers. Gas velocities are maintained well below 45 feet per second to avoid erosion.

The superheaters consist of a horizontal primary superheater located in the convection zone, an intermediate radiant pendant superheater located at the furnace exit, and a final pendant convective superheater located above the furnace "nose" at the exit. The horizontal superheater consists of a loop-in-loop tube bundle with 2-1/4" O.D. tubes in 6" transverse spacing and 5" vertical spacing. The pendant superheater consists of 2-1/4" O.D. tubes on 6" centers at the steam outlet. As the gas temperature becomes progressively hotter, wider spacing is used. The intermediate pendant section has a tube spacing of 12" by 5" and the section exposed to the hottest gases, the radiant section, has a tube spacing of 24" by 3-3/4". The furnace exit temperature is defined as the flue gas temperature between the latter two sections and is calculated at 1,835° F.

The boiler is equipped with 8 intervane burners, four on each side of the furnace. This type of burner, illustrated in Figure XI-61, is used for high volatile coal with good ignition


STEAM OUTLET
DRUM
ELEV. 107'-0"
ELEV. 101'-0"
SUPERHEATER
"B"
"B"
PLAN VIEW SECT "B-B"
PLAN VIEW SECT "A-A"
WATER WALLS
ECONOMIZER
ELEV. 75'-0"
BURNERS
"A"
"A"
AIR PREHEATER
ELEV. 34'-0"
ELEV. 24'-3"
MILLS
F.D. FAN
ELEV. 0'-0"
SECTIONAL SIDE ELEVATION


DRUM
ELEV. 107'-0"
ELEV. 101'-0"
PLAN VIEW SECT 'B-B'
PLAN VIEW SECT 'A-A'
"B"
22'-0½" FURNACE WIDTH
26'-1" FURNACE DEPTH
13'-0"
9'-6"
18'-6"
9'-6"
33'-0"
16'-6"
22'-6"
ECONOMIZER
ELEV. 75'-0"
"A"
AIR PREHEATER
ELEV. 34'-6"
ELEV. 28'-0"
ELEV. 24'-3"
DUST COLLECTOR
F.D. FAN
ELEV. 6'-0"
ELEV. 0'-0"
2¾"
3¾"
3¾"
3¾"
DWG. No.

TYPICAL PLAN SECT. THRU FURNACE WALLS
AT CORNERS
FIN TUBE CONSTRUCTION

NOTES

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DIMENSIONS ONLY.

2. ABBREVIATIONS USED ON THIS DRAWING
IN ACCORDANCE WITH AMERICAN STAN
"ABBREVIATIONS FOR USE ON DRAW

LETTER	DATE	BY	DESCRIPTIO

REVISIONS

50 MW
PROTOTYPE
HIGH SULFUR COMBU

DRAWING NUMBER | SCALE: 1/16" &

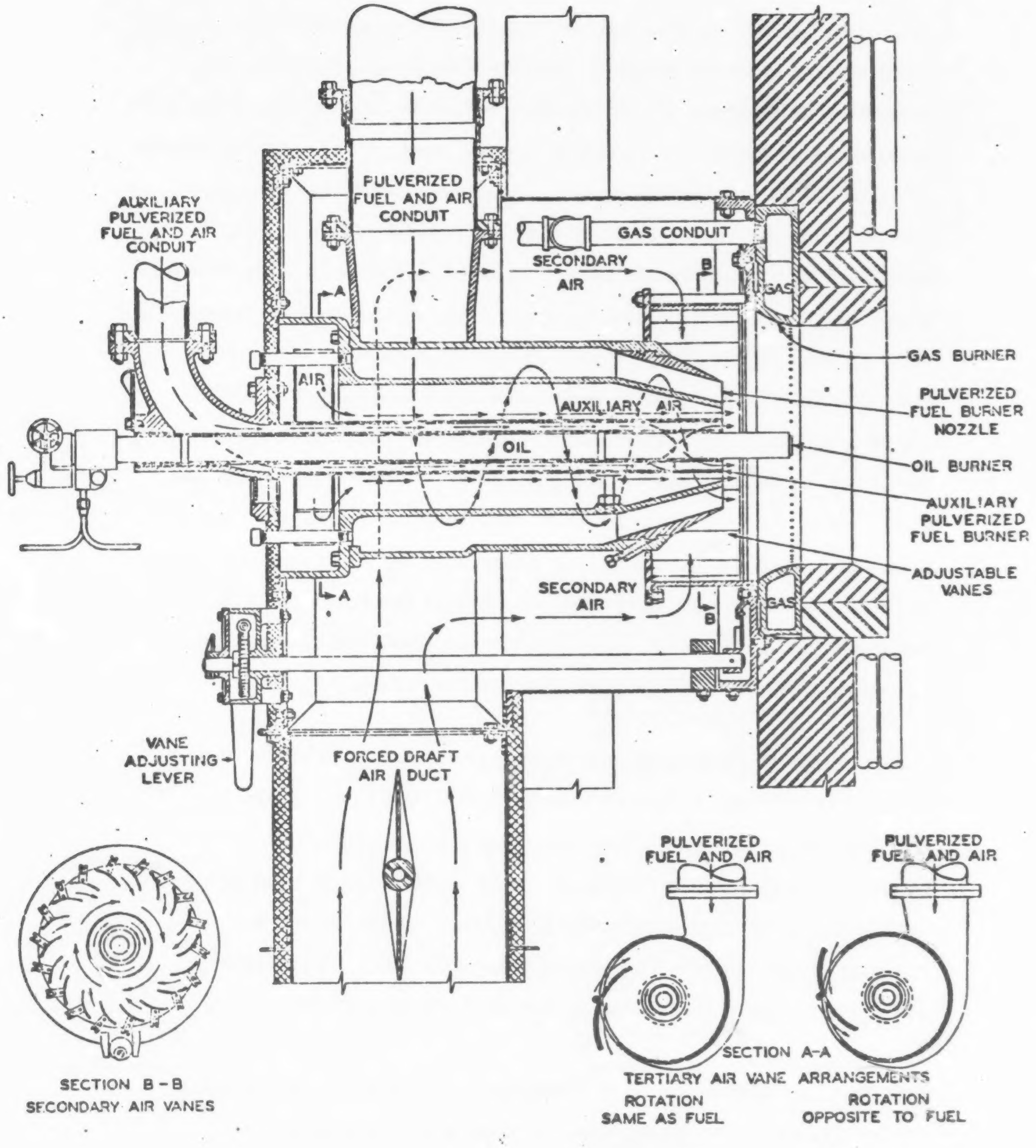
RD-700-51

DWG. MADE & APPROVED BY	INITIAL	DATE	CONT. NO. O-
DRAFTSMAN			
CHECKED			
SQUAD LEADER	T S	5/11/70	
SECTION HEAD			
CONT. SUPV.			

FIGURE XI - 6

THIS DRAWING SUPERSEDES
THIS DRAWING SUPERSEDED BY

FIGURE XI-61


AUXILIARY PULVERIZED FUEL AND AIR CONDUIT
PULVERIZED FUEL AND AIR CONDUIT
GAS CONDUIT
SECONDARY AIR
B
A
GAS
GAS BURNER
AIR
AUXILIARY AIR
PULVERIZED FUEL BURNER NOZZLE
OIL
OIL BURNER
AUXILIARY PULVERIZED FUEL BURNER
ADJUSTABLE VANES
SECONDARY AIR
A
B
GAS
VANE ADJUSTING LEVER
FORCED DRAFT AIR DUCT
PULVERIZED FUEL AND AIR
PULVERIZED FUEL AND AIR
SECTION B - B
SECONDARY AIR VANES
SECTION A-A
TERTIARY AIR VANE ARRANGEMENTS
ROTATION SAME AS FUEL
ROTATION OPPOSITE TO FUEL

HORIZONTAL INTERVANE BURNER EQUIPPED
FOR PULVERIZED COAL, GAS AND OIL FIRING

characteristics. In this burner, the primary air and coal leaving the main nozzle have an angular velocity which is created by the tangential admission of the mixture to the burner body. A similar rotation is given to the coal leaving the auxiliary nozzle by means of vanes located near the outlet. The velocity of the primary mixture leaving these nozzles may be varied by use of the auxiliary air dampers which are located in the exhauster inlets. Secondary air for combustion is admitted to the burner throat through adjustable vanes which control the angular velocity of the secondary air. These vanes are adjustable from 0 to 100 percent open. The rotation of the secondary air is in the same direction as that of the primary mixture. The tertiary air can also be admitted to the burner throat through the angular space between the coal nozzles and is controlled by an adjustable vane to create a rotation either with or against the rotation of the main air-coal stream. This adjustment provides the means for changing the flame shape and furnace conditions.

As a matter of definition, primary air is that part of the transporting air which is injected through the burner nozzles together with the coal. The secondary air is injected into the boiler through the air register. It is introduced to produce a turbulent, uniform, combustible mixture and provide the additional air required to support combustion. The tertiary air is admitted to the center cone as a purging agent.

The furnace liberation at the burner level is 1.7×10^6 Btu/hr-ft^2 (of plan area). This value is reasonably low to avoid slagging problems.

5.4 500 MW Conceptual Design

The 500 MW conceptual design illustrated in Figures XI-62 and XI-63 operates on Fuel "CASE D". Like the 50 MW unit, the steam generator is horizontally opposed-fired with intervane coal burners. Twenty four burners in all are required, served by six ball and tube mills. The 500 MW design is a single reheat pressurized unit in which air is preheated as by a single regenerative air heater fed by two forced draft fans.

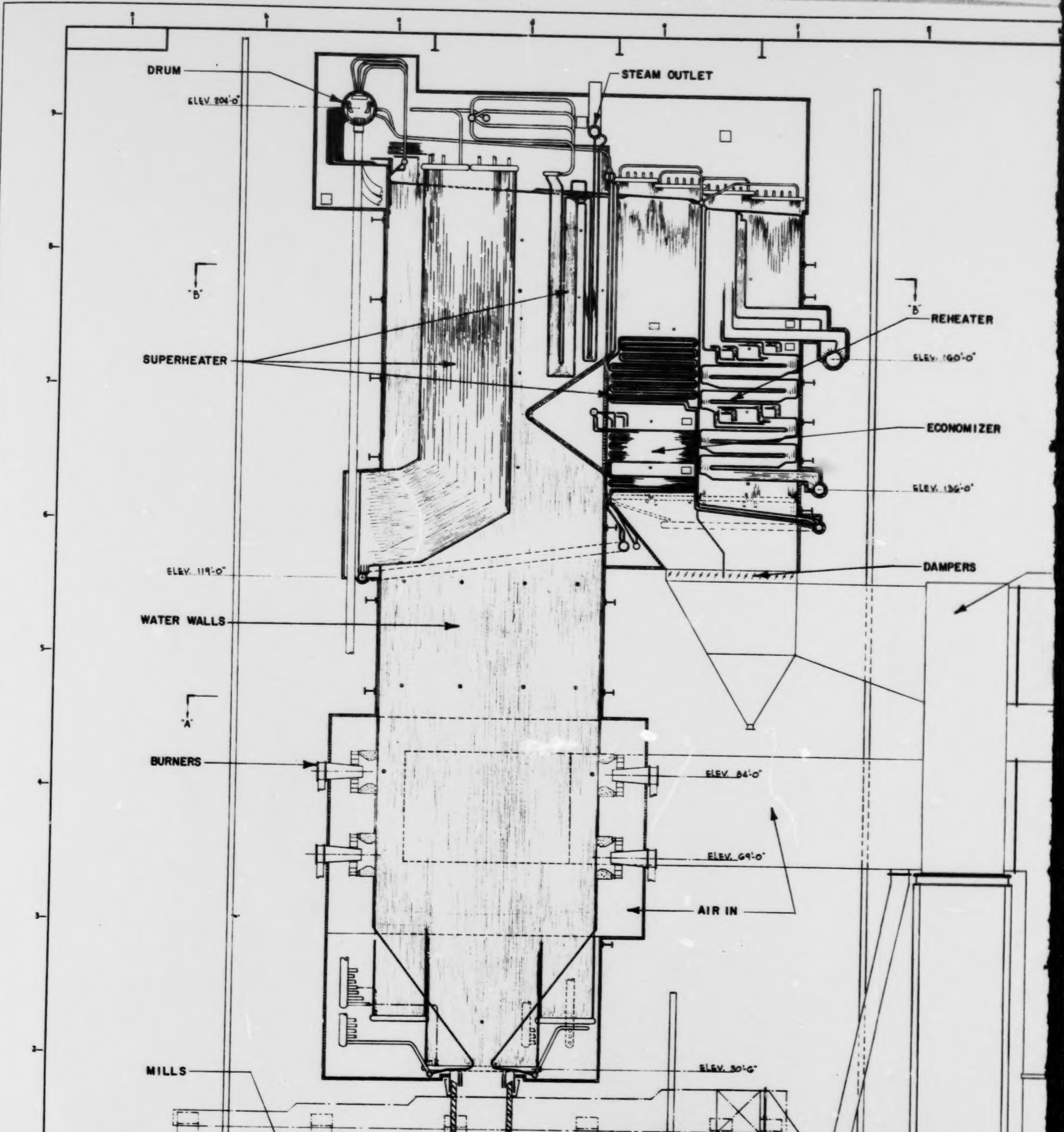
In the reheat cycle, a greater portion of the energy transferred must go to superheating thereby complicating the design. Thus, a smaller portion of the total energy transferred in the furnace goes to evaporation and a larger portion of the surface installed must be devoted to superheating steam. As a result, higher tube metal temperatures are encountered and the risk of fouling is increased. Examination of the energy distribution shows that 28% is used in superheating, 15% in reheating, 18% in evaporating, 21% in feedwater heating,and the remainder, 17%, is lost from the stack.

To accommodate the distribution of energy between these various heating functions, and maintain a reasonable furnace exit temperature, a greater portion of the preheating of the feedwater must be done in the furnace. An increase in furnace size is necessary to facilitiate the installation of additional water wall surface. Also, a large portion of the superheating surface must be radiant and installed in the furnace. To minimize start-up problems and to avoid flame impingement on steam cooled tubes, the radiant superheater is designed as a partial division wall, that is, the upper furnace is compartmentalized in a series of walls made up of superheater tube surfaces. These walls are withdrawn from the furnace above the combustor zone, thereby avoiding plugging problems in the furnace. The distance between platens is about 10 feet. Therefore, the mean radiant beam length is sufficiently large to qualify the surface as radiant surface.

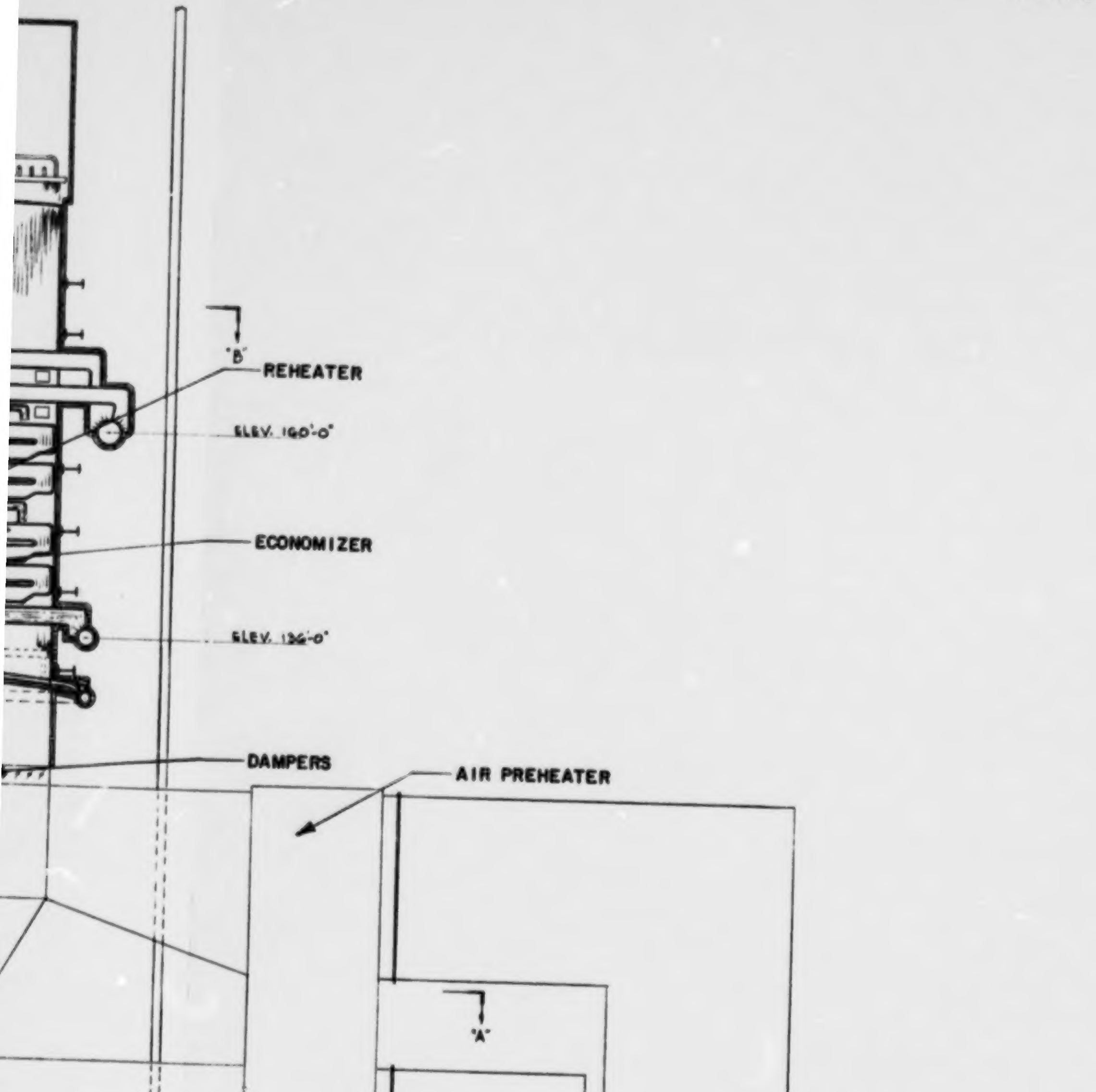
Final superheating is carried out in the pendant superheater which consists of loops of 2-1/4" O.D. tubes on 12" transverse centers in the first loop and 6" transverse centers in the second loop. The tube spacing, front to back, in the division wall and superheater, is 2-3/4". The tubes in both sections are 2-1/2" O.D.

The convection pass is divided in two by a steam cooled division wall of 1-3/4" finned tubes on 3-3/4" centers. The side walls and roof are also cooled by superheated tube element comprised of 1-3/4" O.D. tubes on 3-3/4" centers. The roof tubes are on 1-7/8" centers and carry the saturated steam through the first stage of superheating.

One side of the convection pass is devoted entirely to reheat; the other side is divided between an intermediate stage of superheating and preheat of the feedwater in the economizer. By-pass dampers at the exhaust from the convection pass permit the regulation of gas flow and, therefore, control of reheat superheating. The superheater temperature is partially controlled by balancing the distribution of surface between the


DRUM
ELEV. 204'-0"
STEAM OUTLET
"B"
SUPERHEATER
"B"
REHEATER
ELEV. 160'-0"
ECONOMIZER
ELEV. 136'-0"
ELEV. 119'-0"
DAMPERS
WATER WALLS
"A"
BURNERS
ELEV. 84'-0"
ELEV. 69'-0"
AIR IN
ELEV. 30'-6"
MILLS
1
2
3
4
5
6
7
8
9

REF. DWG.
PLAN VIEW------RD-700-55


"B"
REHEATER
ELEV. 160'-0"
ECONOMIZER
ELEV. 136'-0"
DAMPERS
AIR PREHEATER
"A"
GAS OUT
DUST COLLECTOR
ELEV. 33'-0"
F. D. FAN
ELEV. 0'-0"
ELEV. 0'-0"

NOTES

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2. ABBREVIATIONS USED ON THIS DRAWING ARE IN ACCORDANCE WITH AMERICAN STANDARD "ABBREVIATIONS FOR USE ON DRAWINGS."

REVISIONS

500 MW

HIGH SULFUR COMBUSTOR
(ELEVATIONAL VIEW)

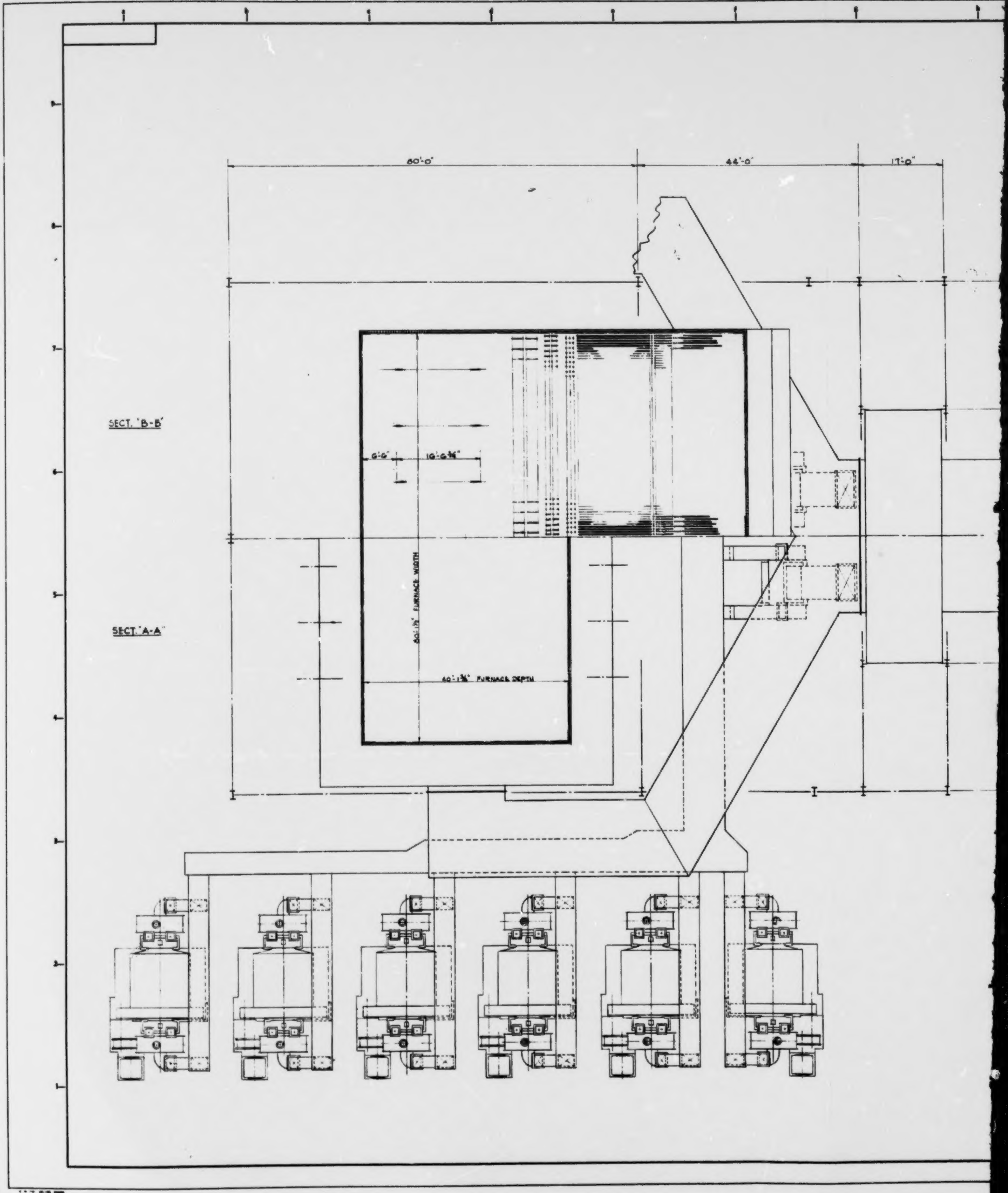
RD-700-54

CONT. NO. 0-59-1177

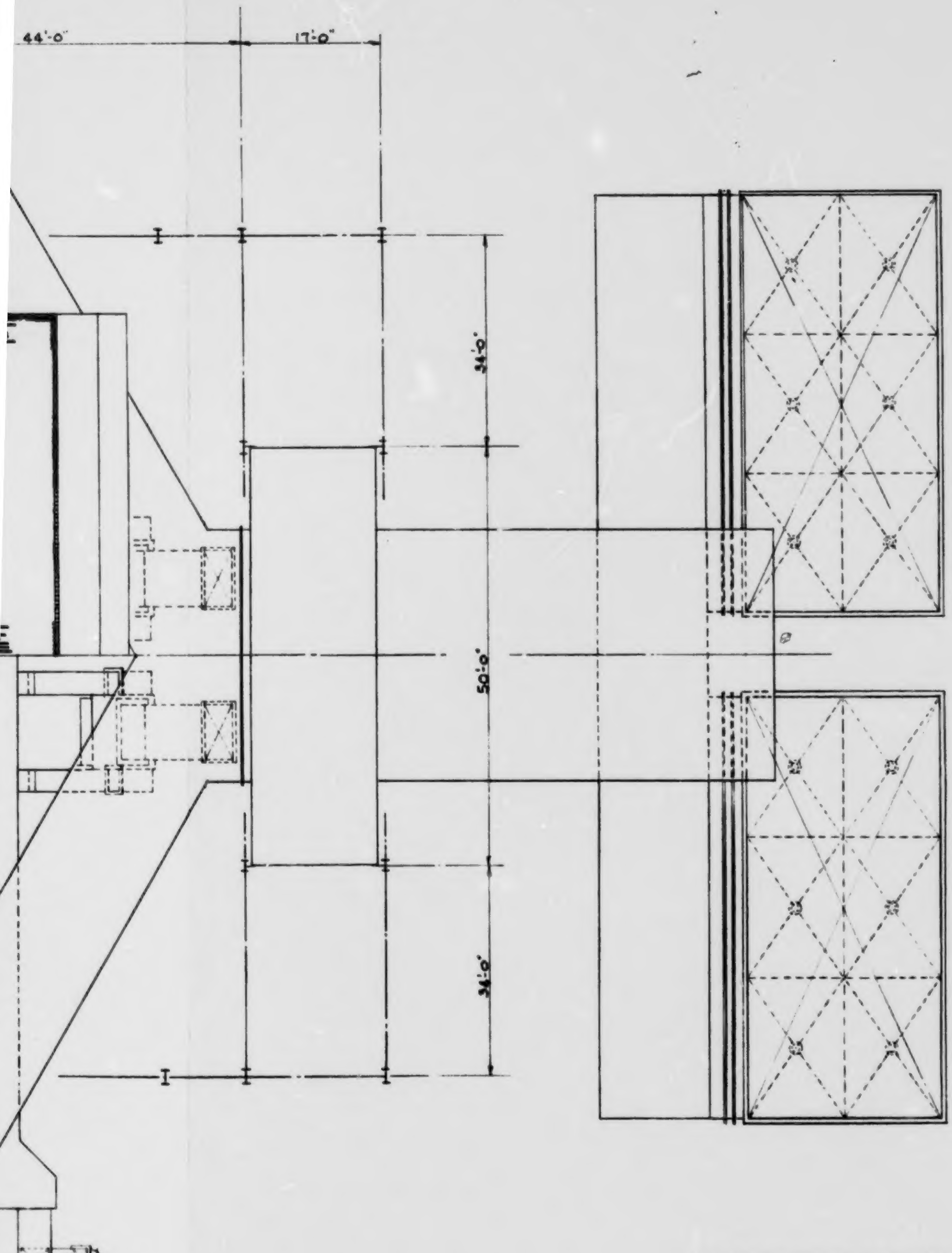
T.S. 6-8-70

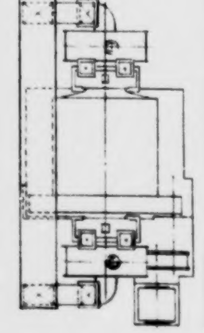
FIGURE XI - 62

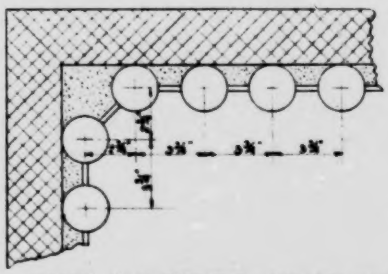
DWG. No.


80'-0"
44'-0"
17'-0"
SECT. "B-B"
SECT. "A-A"
6'-6"
16'-6¾"
60'-1½" FURNACE WIDTH
40'-1¾" FURNACE DEPTH

REF DWG
ELEVATION------RD-700-54







TYPICAL PLAN SECT. THRU FURNACE WALLS
AT CORNERS
FIN TUBE CONSTRUCTION

NOTES

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REVISIONS

500 MW

HIGH SULFUR COMBUSTOR
(PLAN VIEW)

RD-700-55

0-59-1177

T.S. 6-8-70

FIGURE XI - 63

DWG. No.

radiant heat transfer and convection heat transfer, and by using a superheater control condenser between the division wall and final pendant section.

Reheater tubes are 2-1/2" O.D. tubes on 6" transverse centers and 5" vertical centers. At the point at which the tubes are withdrawn to the headers the transverse spacing is increased to 12" for structural reasons.

The horizontal convective superheater consists of 2-1/2" O.D. tubes on 6" transverse centers and 5" vertical centers. The economizer is a bare tube, single loop bundle of 2" O.D. tubes on 4" vertical spacing and 6" transverse spacing. Gas velocities have been kept below 45 feet per second throughout the convective passes.

All efforts have been directed in this unit at keeping all headers out of the gas pass so that they are not subject to the effects of high gas temperatures.

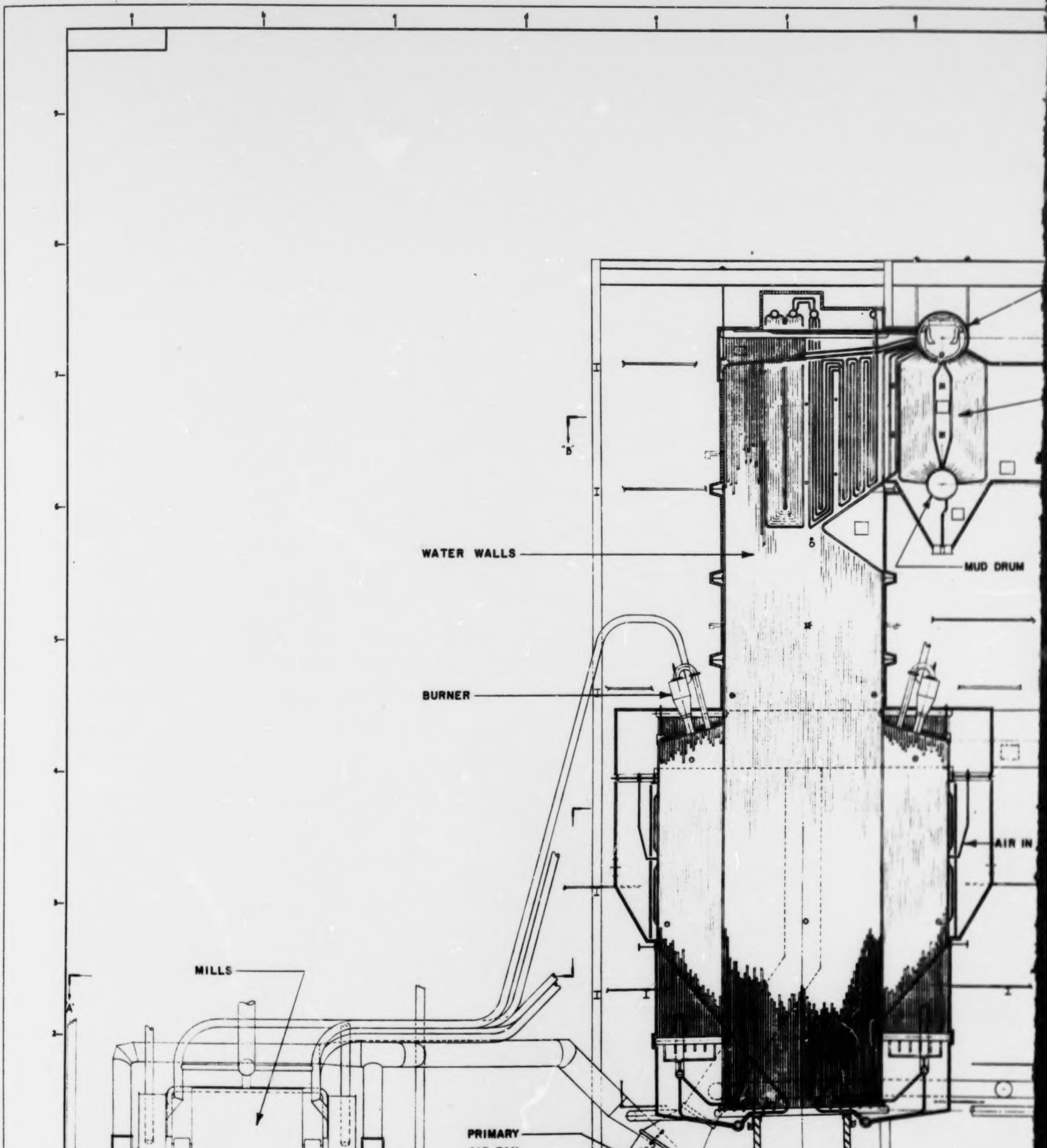
The drum on the unit is 66" O.D. x 80 feet in length. Two 10" O.D. downcomers permit recirculation of the slightly subsaturated water to the lower water wall headers which, in turn, feed the evaporator tubes.

The furnace heat liberation rate in the plan of the burner is 1.6×10^6 Btu/hr-ft^2, sufficiently low so as to avoid excessive slagging in the furnace.

5.5 500,000 Lb/Hr Industrial Boiler

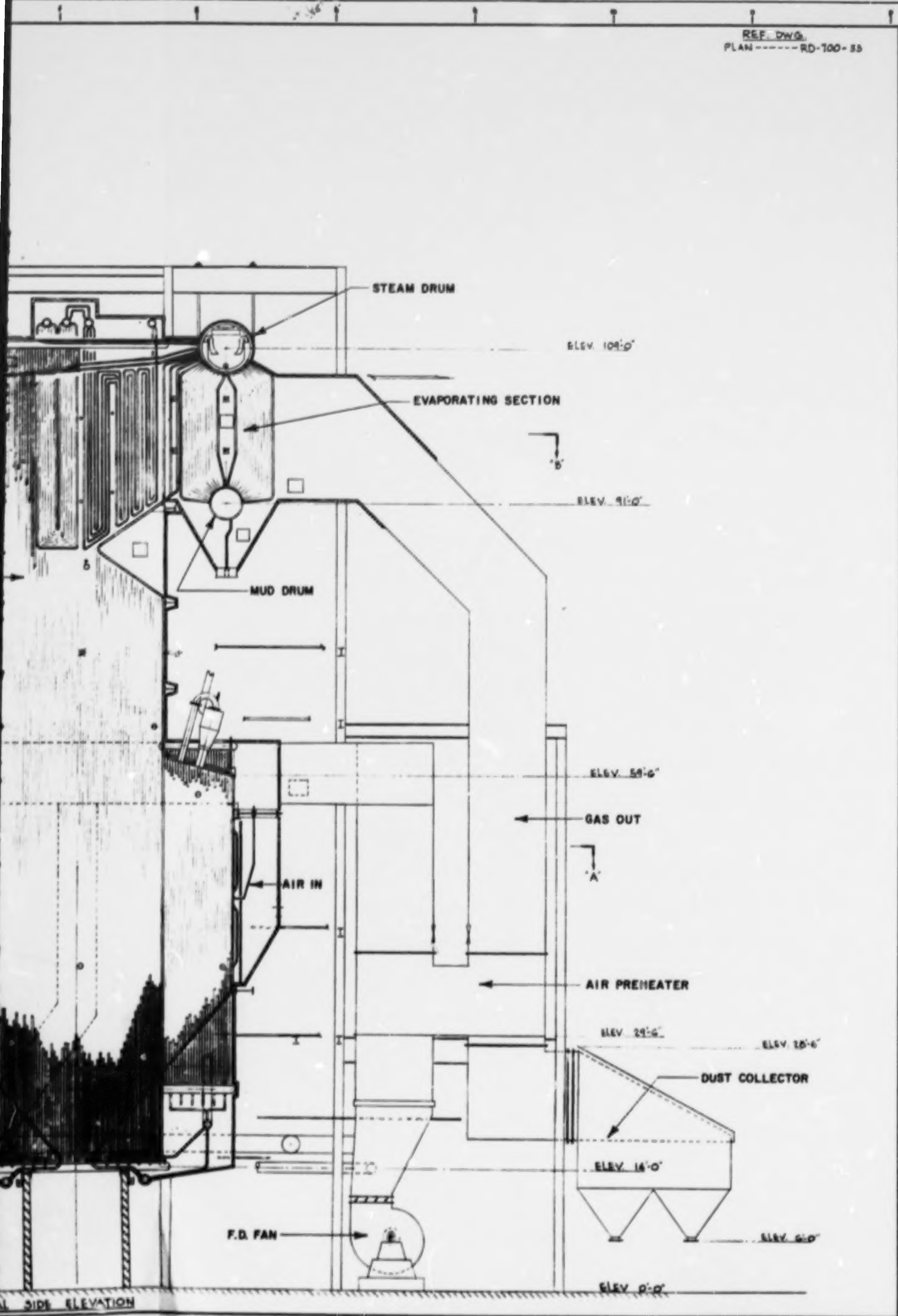
The 500,000 lb/hr industrial boiler illustrated in Figures XI-64 and XI-65 operates on HSC Fuel of the CASE A composition. This boiler is completely different from the utility boiler designs because of the fuel character and the cycle selected.

In this design, the HSC Fuel is fired downward permitting introduction of secondary air through the furnace wall, as needed, along the path of combustion. Separating type burners, in which the bulk of the carrier air is separated, produce a fuel-rich mixture which is blown into the combustion zone. A schematic diagram of this burner is shown in Figure XI-66. The air-cooled mixture flowing into the burners passes through a riffle distributor designed to distribute coal uniformly to the air-coal splitter box. The burner cyclones separate the bulk of the air from the mixture by centrifugal action, and the separated air turns into the burner vent pipe which directs its flow into the furnace. Operational control to help maintain the ignition point at optimum conditions is provided by the burner vent control damper. Burner vanes in the coal nozzle straighten out the coal stream and aid in driving the fuel down through the ignition zone. Hot tertiary air is brought into the annular openings around the burner nozzles in a laminar flow, stripping the air-coal stream and separating the burned molecules.


WATER WALLS
BURNER
MILLS
PRIMARY AIR FAN
MUD DRUM
AIR IN
F.D. FAN
"B"
"A"
1
2
3
4
5
6
7
8
9

SECTIONAL SIDE ELEVATION

REF. DWG.
PLAN ------- RD-700-53


STEAM DRUM
ELEV. 109'-0"
EVAPORATING SECTION
'B'
ELEV. 91'-0"
MUD DRUM
ELEV. 59'-6"
GAS OUT
'A'
AIR IN
AIR PREHEATER
ELEV. 29'-6"
ELEV. 28'-6"
DUST COLLECTOR
ELEV. 14'-0"
F.D. FAN
ELEV. 6'-0"
ELEV. 0'-0"
AL SIDE ELEVATION

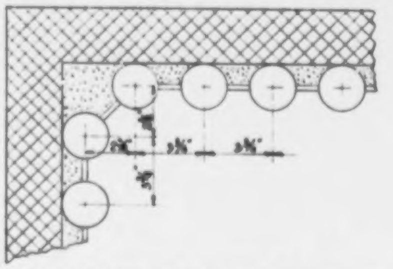
500,000 lb/HR
INDUSTRIAL
HIGH SULFUR COMBUSTOR
(ELEVATIONAL VIEW)

RD-700-52

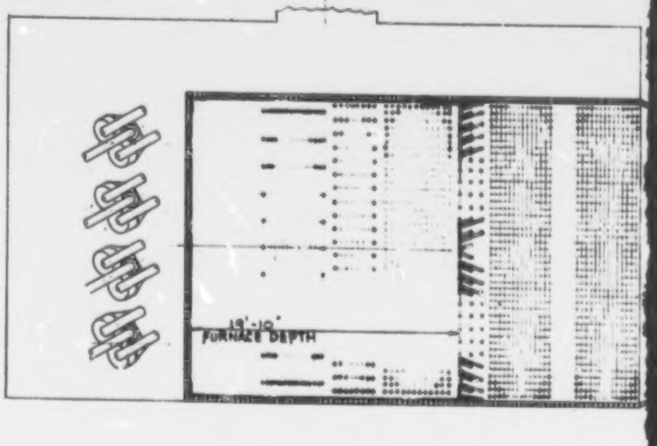
0-59-1177

FIGURE XI - 64

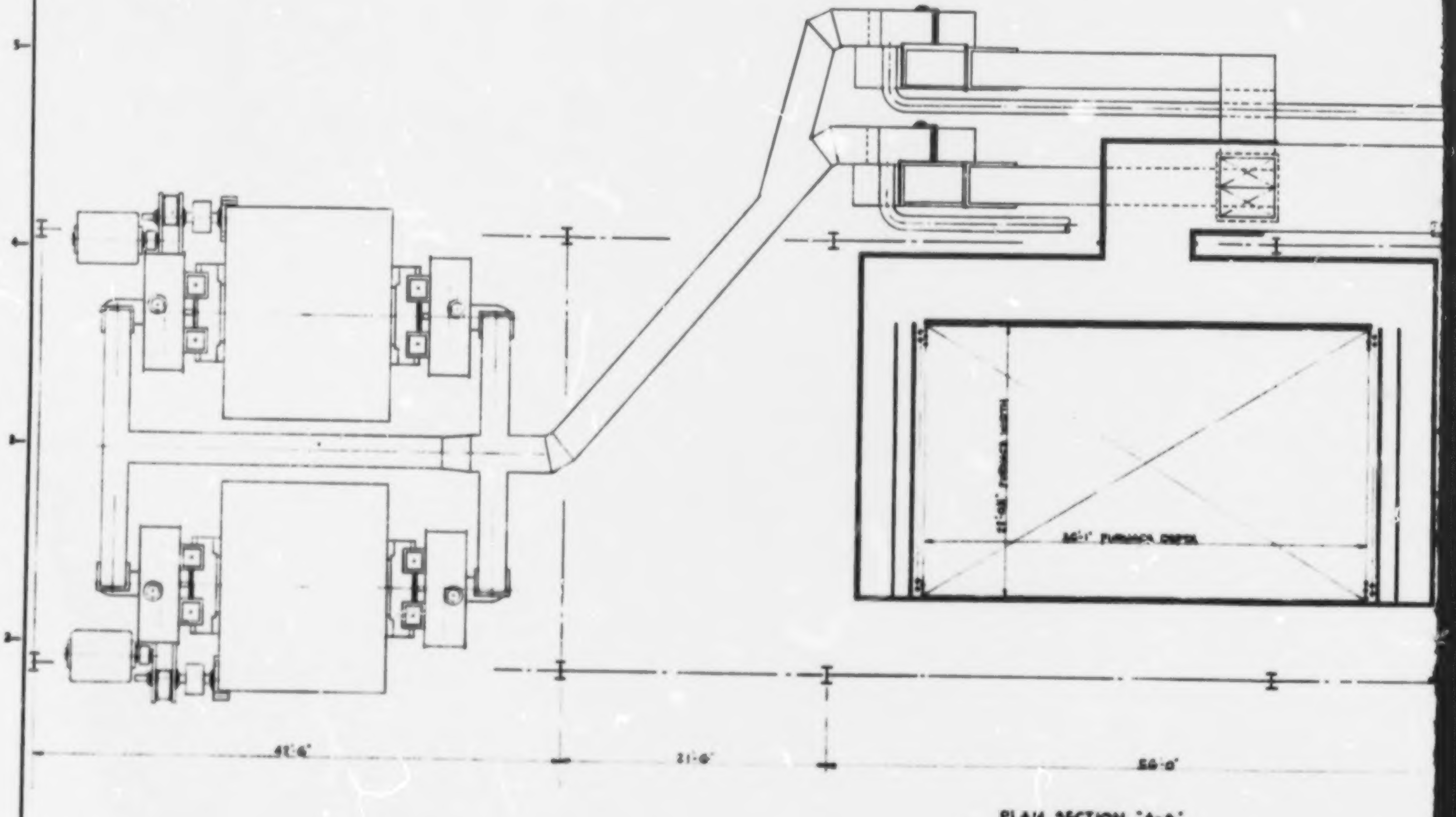
DWG. No.



TYPICAL PLAN SECT. THRU FURNACE WALLS AT CORNERS FIN TUBE CONSTRUCTION

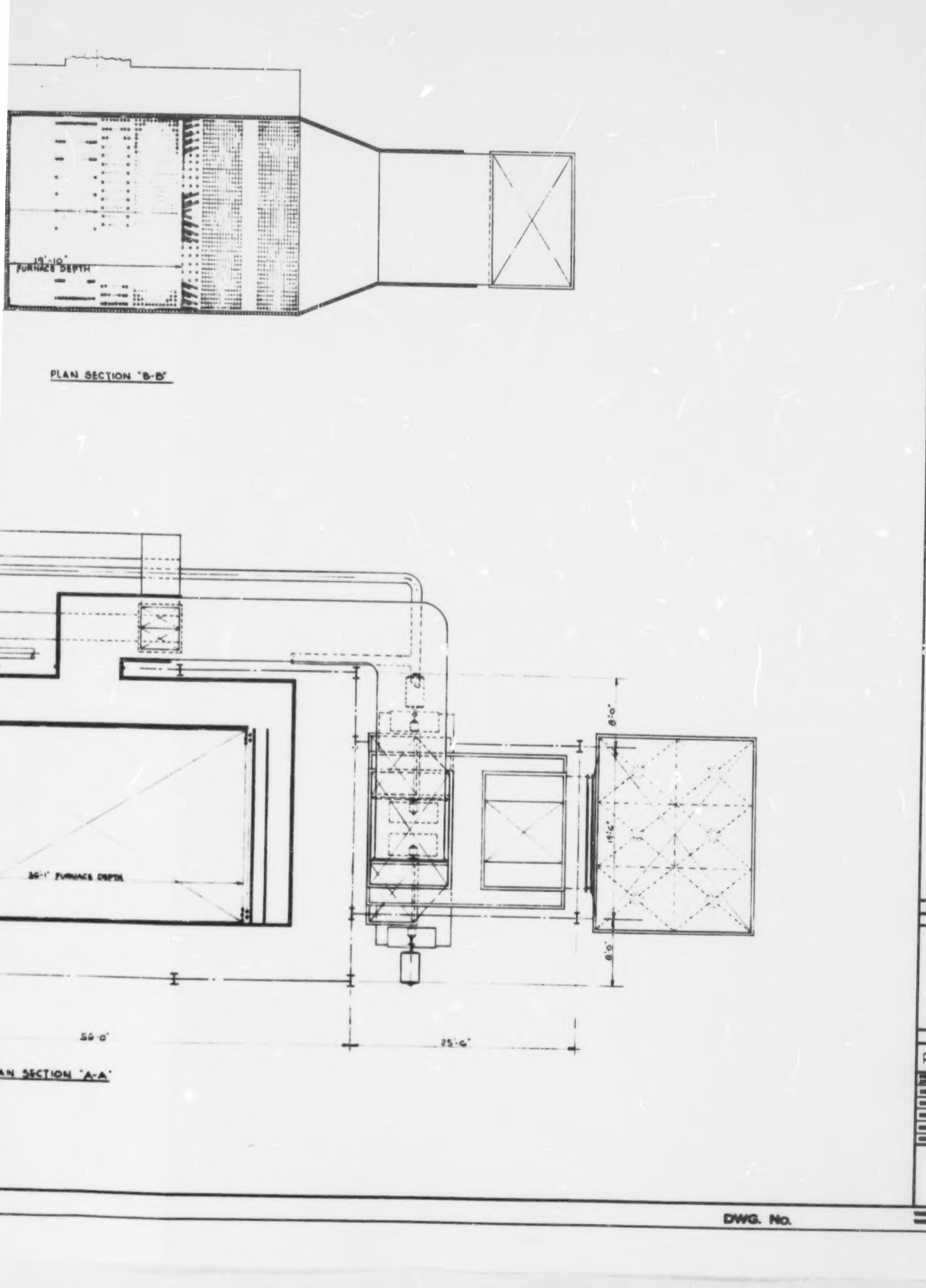

19'-10"
FURNACE DEPTH

PLAN SECTION "B-B"


21'-6" FURNACE WIDTH
36'-1" FURNACE DEPTH
42'-6"
21'-6"
56'-0"

PLAN SECTION "A-A"

REF. DWG.
ELEVATION ---- RD-700-52


19'-10"
FURNACE DEPTH
PLAN SECTION "B-B"
36'-1" FURNACE DEPTH
8'-0"
19'-6"
8'-0"
56'-0"
25'-6"
AN SECTION "A-A"

NOTES

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REVISIONS

500,000 LB/HR
INDUSTRIAL
HIGH SULFUR COMBUSTOR
(PLAN VIEWS)

SCALE 3/16"

RD-700-53

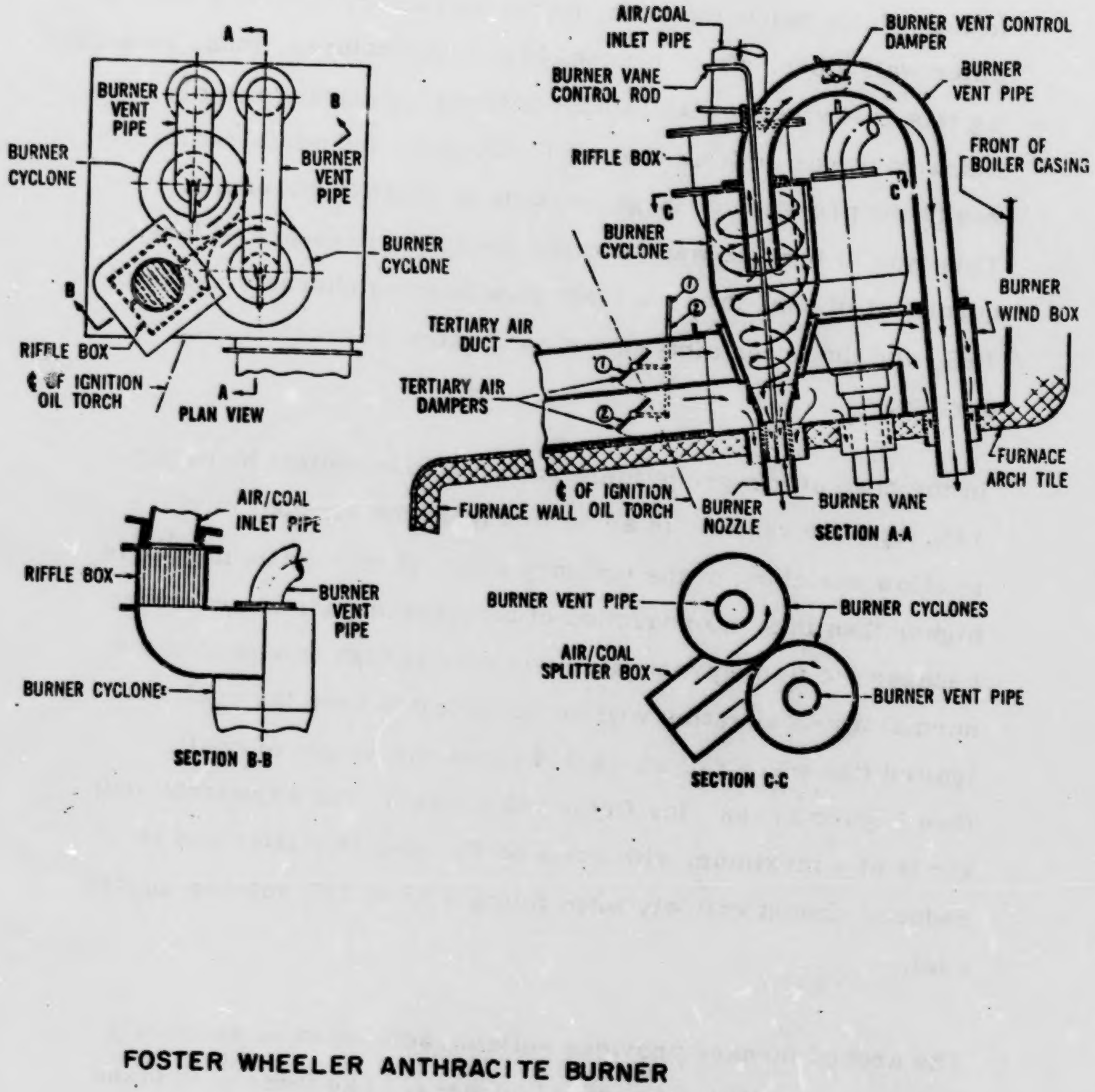
CONT. NO. 0-59-1177

T.S. 5/29/70

FIGURE XI - 65

DWG. No.

FIGURE XI - 66


A
B
BURNER VENT PIPE
BURNER CYCLONE
BURNER VENT PIPE
BURNER CYCLONE
B
RIFFLE BOX
℄ OF IGNITION OIL TORCH
A
PLAN VIEW
AIR/COAL INLET PIPE
BURNER VENT CONTROL DAMPER
BURNER VANE CONTROL ROD
BURNER VENT PIPE
RIFFLE BOX
FRONT OF BOILER CASING
C
C
BURNER CYCLONE
①
②
BURNER WIND BOX
TERTIARY AIR DUCT
TERTIARY AIR DAMPERS
①
②
FURNACE ARCH TILE
FURNACE WALL
℄ OF IGNITION OIL TORCH
BURNER NOZZLE
BURNER VANE
SECTION A-A
AIR/COAL INLET PIPE
RIFFLE BOX
BURNER VENT PIPE
BURNER CYCLONE
SECTION B-B
BURNER VENT PIPE
BURNER CYCLONES
AIR/COAL SPLITTER BOX
BURNER VENT PIPE
SECTION C-C

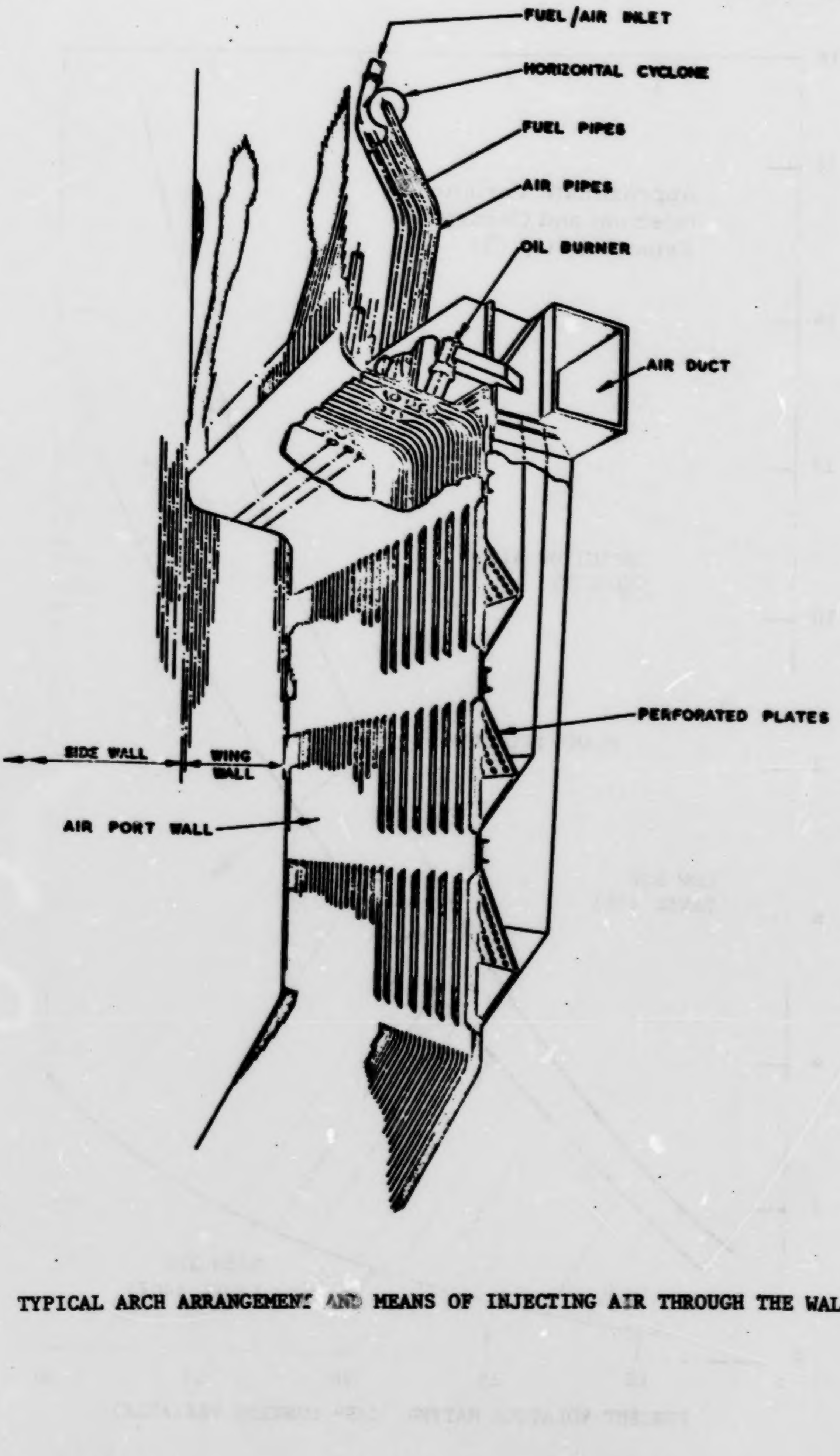
FOSTER WHEELER ANTHRACITE BURNER

Secondary air is selectively introduced into the furnace through openings in the vertical wall, feeding oxygen along the path of the burning coal to obtain the maximum practical degree of burn-out. This is illustrated in a typical arch arrangement shown in Figure XI-67. Combustion of the low volatility coal is assisted, in the volume below the arch, by the refractory covering over the water wall tubes, which reaches high temperatures, thus, penetrating this coal stream with radiant heat throughout the furnace. Refractory was omitted in the 500,000 lb/hr industrial boiler due to the presence of large amounts of volatile materials. This type of furnace was selected due to the presence of large quantities of ash, the relatively slow burning characteristics of FeS, and the uncertainty of the combustion characteristics of pyrites.

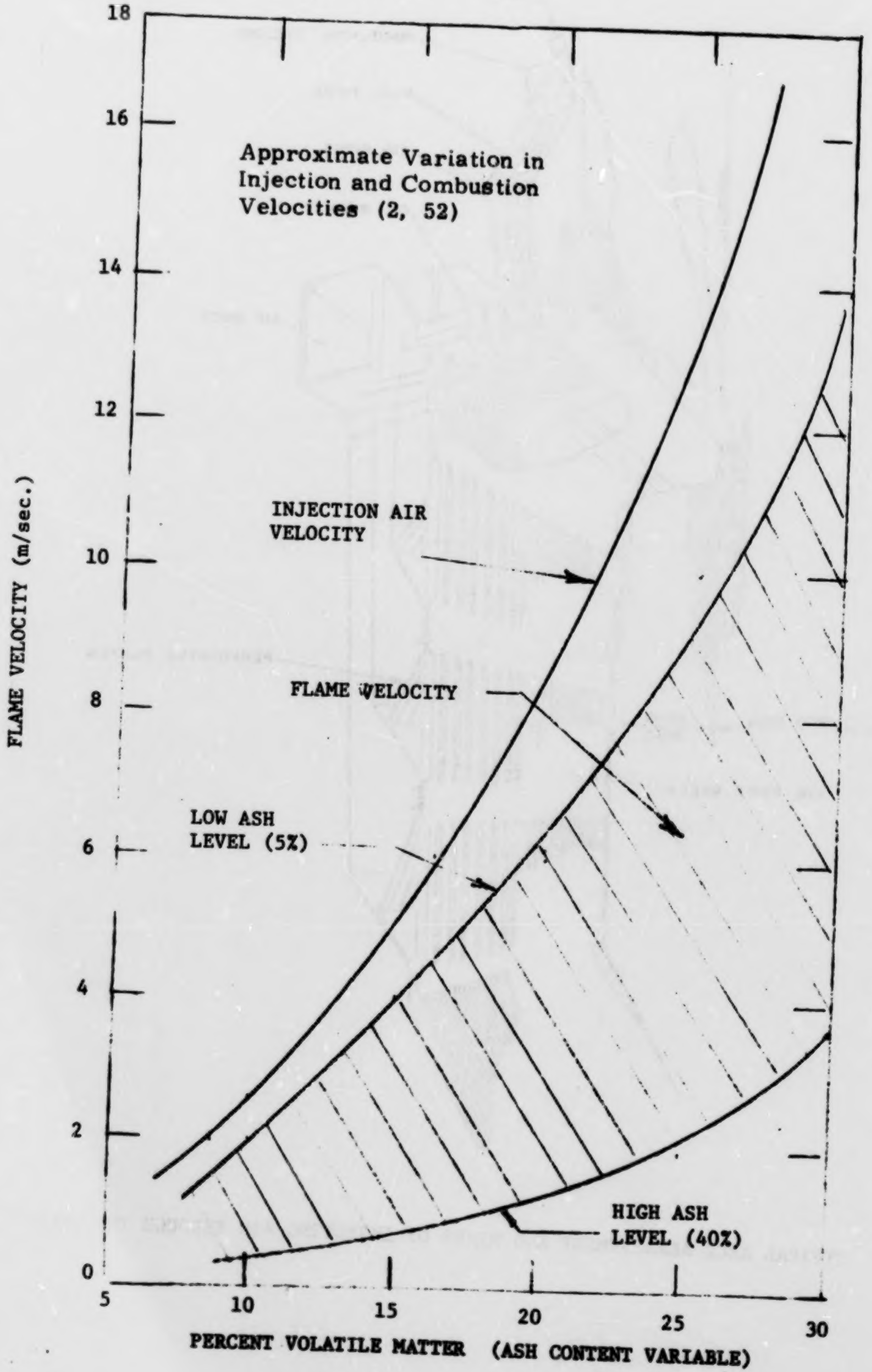
In the case of low grade fuels, with volatile content below 12-14%, cyclone vent air is separated from the air-coal mixture to allow enriching of the primary air. When volatile matter is higher than this, no reduction of transporting air is necessary because the flame propagation velocity is high enough that the normal air-coal ratios will be sufficient to keep the coal ignited (the weight of air is 1.4 times the weight of coal). (See Figure XI-68 for flame velocities.) The adjustable vent air is at a maximum with coals of 6% volatile matter and is reduced almost entirely when firing a 12 to 14% volatile matter coal.

The arched furnace provides suitable admission of secondary air and adaptability of vertical burners. The furnace is sized so that the imaginary flame paths form two long loops

FIGURE XI - 67


FUEL/AIR INLET
HORIZONTAL CYCLONE
FUEL PIPES
AIR PIPES
OIL BURNER
AIR DUCT
PERFORATED PLATES
SIDE WALL
WING WALL
AIR PORT WALL

TYPICAL ARCH ARRANGEMENT AND MEANS OF INJECTING AIR THROUGH THE WALLS


Approximate Variation in Injection and Combustion Velocities (2, 52)
FLAME VELOCITY (m/sec.)
18
16
14
12
10
8
6
4
2
0
INJECTION AIR VELOCITY
FLAME VELOCITY
LOW ASH LEVEL (5%)
HIGH ASH LEVEL (40%)
5
10
15
20
25
30
PERCENT VOLATILE MATTER (ASH CONTENT VARIABLE)

intersecting at a point in the center of the furnace. This produces sufficient turbulence to insure combustion prior to entering the vertical duct forming the furnace exit.

The cycle for the industrial boiler is quite different from the other two units. Only 14% of the energy transferred is consumed in generating superheat; 43% is used in evaporating water; 17% in preheating feedwater, and 24% is lost from the stack. Although the air preheater flue gas exit temperature is identical to the other two units, the heat losses have increased due to the decrease in heating value of the fuel and are not compensated by the reduction of the gas and air-fuel ratio.

Further complications arise due to the lower feedwater temperatures and the potential for condensation of sulfuric acid on the economizer tube surfaces. To avoid this problem, the feedwater is fed directly to the drum, thereby improving circulation, but at the same time increasing the evaporating surface requirements of the furnace. Instead of cooling the furnace down and risking possible flame instabilities, the design was modified to include a vertical convective evaporating section downstream of the superheater, requiring a two drum boiler. One drum, the steam separating drum, is 66" in diameter and 22 feet long. The other drum is 44" in diameter. Two inch O.D. tubes are used on 6" transverse centers with 4" longitudinal centers.

Three banks of pendant superheaters are installed at the furnace exit. The pendant section in the highest gas temperature zone consists of 2-1/4" O.D. tubes on 24" transverse centers. The intermediate pendant superheater consists of 2-1/4" O.D. tubes on 12" transverse centers, and the final superheater consists of 2-1/4" O.D. tubes on 6" transverse centerline. This unit is served by two ball and tube mills, two forced draft fans, and two primary air fans.

5.6 Cost Estimates of HSC Fired Boiler Systems

The total estimated costs for the three boilers, including erection, are shown in Table XI-14 below: -

TABLE XI-14

Cost Details for Three HSC Fired Boiler Systems

Equipment	500 MW	50 MW	500, 000 lb/hr
Boiler*	$15, 761, 325	$4, 313, 000	$5, 113, 312
Accessories			
Feeders	81, 304	27, 128	27, 128
Air Preheater	592, 000	55, 000	85, 000
Soot Blowers	301, 000	69, 341	51, 553
Mech. Dust Collectors	155, 000	20, 500	25, 500
Forced Draft Fans	83, 000	21, 500	15, 000
Primary Air Fans	68, 000	18, 500	26, 000
Sealing Air Fans	4, 950	1, 850	1, 650
Grinding Mills	600, 000	142, 000	205, 000
Totals	$17, 646, 599	$4, 668, 819	$5, 550, 143

* Including Erection Costs

6. TEST PROCEDURES

Tests that should be performed as part of standard procedure for preparing, controlling, and defining HSC Fuels should include:

1) Ultimate Analysis
2) Proximate Analysis
3) Heating Value
4) Hardgrove Grindability
5) Reactivity (Ignition Index)
6) Chemical Analysis of Ash
7) Ash Fusion, Reducing and Oxidizing Atmosphere
8) Size Analysis
9) Free Swelling Index

These tests are essential. Others, such as burning rates and abrasion index, are desirable. The latter should provide the designer with the reassurance necessary to produce the most economical design. Standard tests have not yet been developed in these areas, nor has a relation been developed between existing indices and field experience or design practice. Ultimately, it may prove to be most beneficial to relate such characteristics as burning rate index to other fuel characteristics more frequently analyzed. Work in this area is recommended.

6.1 Standard Coal Tests

The specific test procedure need not be defined for most of the tests as they are described in detail by the American Society of Testing Materials. These tests include the following:

TABLE XI - 15

ASTM TEST DESIGNATION

1)	Proximate Analysis	ASTM Desig. :	D271-58
2)	Ultimate Analysis	ASTM Desig. :	D271-58
3)	Heating Value	ASTM Desig. :	D271-58
4)	Hardgrove Grindability	ASTM Desig. :	D409-37T
5)	Ash Fusion	ASTM Desig. :	D1857-61T
6)	Free Swelling Index	ASTM Desig. :	D720-57
7)	Size	ASTM Desig. :	D410-38

6.2 Chemical Analyses

Chemical analyses are not as straight-forward as the tests listed above. Different tools are used by each laboratory to expedite the analyzing procedure. Old procedures are replaced with new at frequent intervals as improved techniques are developed or new techniques become available. For this reason, specific details are not discussed. The elements that should be analyzed for are listed, along with several test procedures that may be used:

TABLE XI - 16
SEVERAL TEST PROCEDURES

Element	I Wet Analysis	II X-Ray Fluorescence	III Emission Spectrograph	IV Atomic Absorption
Al	gravimetric	A*	A	A
Si	gravimetric	A*	A	A
Fe	volumetric	A*	A	A
Ca	gravimetric	A*	A	A
Mg	gravimetric	A*	A	A
Na	flame photometer	A*	A	A
K	flame photometer	A*	A	A
Ti	calorimetric	A*	N. A.	N. A.
P	calorimetric	A*	N. A.	N. A.

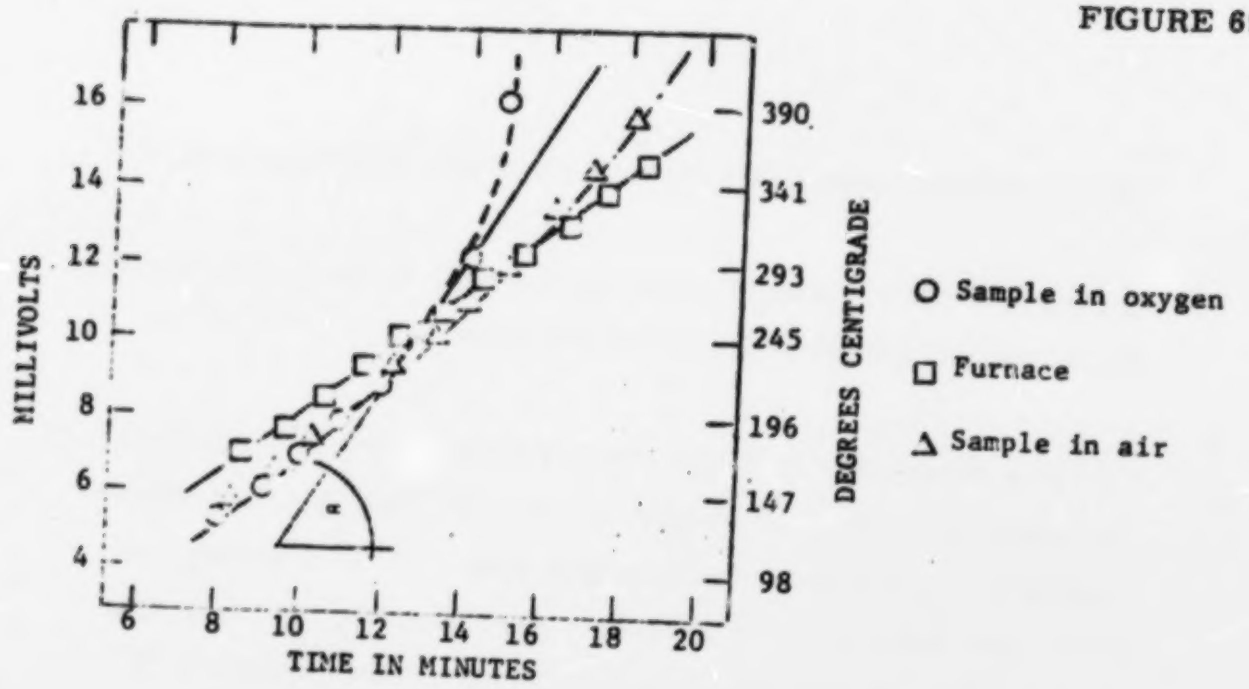
* = Preferred
A = Applicable
N. A. = Not Applicable

6.3 Reactivity Tests

Of the nine standard tests only one is not commonly accepted and that is reactivity. This test has been the subject of much investigation as earlier indicated. It is recommended in preference to simple ignition tests or the practice of using volatility or some other distinguishing physical feature of coal as an index of the combustibility of coal. Reactivity appears to be the best indicator of combustion conditions over a wide range of fuel specifications.

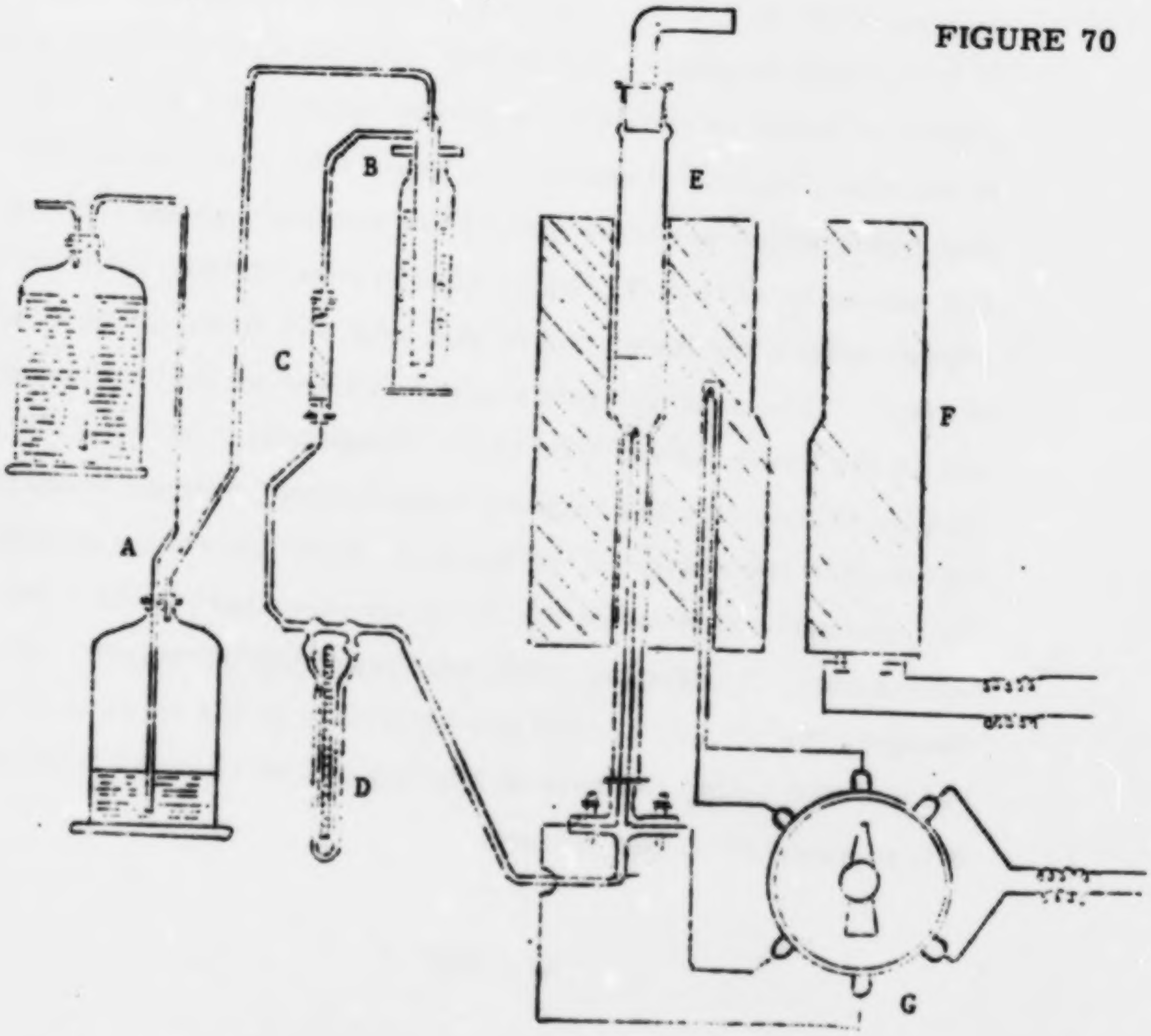
Reactivity index is defined as the temperature in degrees Centigrade at which the adiabatic self-heating rate is 15 degrees Centigrade rise per minute in pure oxygen. It is determined by first establishing the crossing temperatures, or the points at which the self heating rate exceeds the furnace rate in oxygen and in air. The heating rates and temperature levels are then used to establish the empirical constants in the Arrhenius equations relating reaction rate to temperature. These constants are characteristic of each fuel. Once they are determined it is possible to compare the reaction rates of different fuels at the same temperature or to determine the temperatures at which different fuels have the same reactivity towards oxygen. It also becomes possible to calculate the specific index, T_{15}, which has been found to be highly meaningful. Samples of data collected, along with a graphical solution for the constants in the Arrhenius equation, appear in Figure XI-69. Sample calculations are illustrated in Table XI-17.

FIGURE 69



TYPICAL TEMPERATURE-TIME REACTIVITY CURVES

FIGURE 70



DIAGRAMMATIC LAYOUT OF REACTIVITY APPARATUS

The equipment used in this test is illustrated in Figure XI-70.

It consists of two parallel heating channels in the same furnace. Each channel contains the following units:

"A" is a gasometer of 5-gallons (19-liter) capacity, supplying the reaction tubes with oxygen or air; "B" is a micropressure regulator to provide a constant gas flow; "C" is a drying tube filled with Anhydrone (magnesium perchlorate); "D" is a flowmeter; "E" is a reaction tube fitted into a hole drilled in "F" a vertical cast-iron cylinder heated by a Nichrome winding. The reaction tube contains a 1-inch (2.5-cm.) layer of granular sample resting on a platinum gauze plug. The sample has a volume of about 1.3 cc. and weighs about 0.75 gram. The tip of a Chromel-Alumel thermocouple extends into the sample to whatever height is desired. A ground-glass joint at the bottom of the reaction tube connects to a glass tube with two horizontal side arms which serve as outlets for the thermocouple leads and are sealed by screw clamps on short rubber tubes. The air or oxygen enters the lower end of this tube and flows upward through the fuel. The reaction tubes are supported so that the samples are in the center of the iron block, lengthwise. A third thermocouple, to measure the furnace temperature, extends from the bottom into the center of the furnace block. A rotary switch, "G", connects any one of the three thermocouples with a potentiometer, facilitating rapid reading of temperatures. By changing the e.m.f. across the terminals of the furnace between 110 and 220 volts, the rate of heating can be changed from about 6° C to about 25° C per minute.

The procedure for running a test requires measuring a sample of coal in a small glass beaker which is a duplicate of the space within the reaction tube. The sample used should be sized through the #40 or #60 United States standard sieve. Experimentation indicates this size appears to be most reasonable for a heterogeneous sample. The beaker containing the sample is tapped and additional coal is added until a space just one inch long is filled to maximum bulk density. The sample is then poured into the reaction tube which is then tapped and tamped until the coke fills just the same volume in the reaction tube; this volume is gauged by a scratched mark in the tamping rod. Two reaction tubes filled according to the procedure described are then fixed in place, gas connections are made, and the air and oxygen are started flowing and adjusted to their fixed flow rates of 85 cc per minute. The current to the furnace is then turned on and frequent readings are made of both samples and of the furnace, starting far enough below the ignition point so that at least five readings have been obtained when one value of sample temperature well above the furnace temperature is reached. The usual period between readings is one minute, but for slow heating rates this period may be increased. In each case, the temperature of the sample in oxygen is read first, followed 15 seconds afterwards by the temperature of the sample in air and 15 seconds later by the furnace temperature. The 15 second intervals between each reading are taken into consideration when the data are plotted or the results are calculated.

The arrangement of the apparatus must be such as to satisfy the following conditions:

1) **Sufficient oxygen must be supplied by the oxidizing gas stream so that its concentration throughout the sample column is effectively constant at the ignition point.**

2) **The gas stream must reach the temperature of the sample charge before it comes in contact with it so that $T_a = T$.**

3) **The heat evolved must be immediately indicated by temperature rise and not dissipated.**

4) **The temperature of the sample should be uniform when the ignition point is reached.**

5) **The curves representing sample and furnace temperature must cross sharply enough to permit precise determination of the ignition temperature and the time rate of increase of sample to temperature.**

The apparatus and procedure described were tested rather extensively by varying the operating parameters and test procedure. Both the apparatus and the procedure were found to satisfactorily fulfill all five conditions specified.

The data, which include time and millivolts for the two samples in the furnace atmosphere, are plotted on a time-temperature curve.

From the heat balance of the sample whose ignition point is being determined, it can be shown that the slope of the curve divided by the partial pressure of the oxygen is proportional to the absolute reaction rate per unit of pressure of oxygen. Thus;

$$c\frac{dT}{dt} = m(T_f - T) - n(T - T_a) + Hup \qquad (1)$$

where: (in consistent units)

c = specific heat of sample

t = time

T, T_a, T_f = Temperature of sample, oxidizing gas stream and furnace, respectively

m = coefficient of heat transfer between furnace and sample

n = coefficient of heat transfer between sample and oxidizing gas stream

H = heat of combustion

u = absolute reaction rate per unit pressure of oxygen

p = oxygen partial pressure

If the ignition point is taken as the point at which the line representing the sample temperature plotted against time crosses the furnace temperature line, and if the apparatus is so arranged that the oxidizing gas temperature is always equal to the coke temperature where it reaches the sample, then at the ignition temperature:

$$T = T_a = T_f$$

$$u = \frac{C}{Hp.}\frac{dT}{dt} = \frac{C}{Hp}\tan\alpha \qquad (2)$$

where:

$$\frac{1}{p}\tan\alpha$$

The partial pressure and "ignition temperatures" are known and the tangent of α can be determined graphically. Since the data were established for two cases, both empirical constants, b and E, in the Arrhenius equation, can be solved for:

$$\mathrm{Log}_e u = b - \frac{E}{RT} \qquad (3)$$

where R is the gas constant and
T is absolute temperature

The reactivity index was originally defined as the temperature level at which the rate of self-heating was 15 degrees centigrade per minute. The Arrhenius equation has been defined for the sample in question and it can now be used to calculate the reactivity index or T_{15}.

Sample calculations appear in Table XI-17 to clarify the previous discussion. For more detailed discussions of the reactivity test refer to:

> V. V. S. Sebastian and M. A. Mayer, "Coke Reactivity Determination by a Modified Ignition Point Method," Industrial and Engineering Chemistry, Vol. 29, No. 10, October 1937.

TABLE XI - 17

SAMPLE CALCULATION

Reactivity Index - Fairmont Coke

Oxygen

The crossing point of oxygen and furnace curves was 10.2 mv. This is equivalent to 245° C or 518° K. The tangent to the oxygen curve at the point was found as follows:

At the 16-minute ordinate	15.0 mv	366° C
At the 10-minute ordinate	6.0 mv	147° C
		219° C

Tangent of α = 36.3 (oxygen)

where (in consistent units):

$$\mathrm{Ln}\,\frac{1}{P}\,\tan.\,\alpha = b - \frac{E}{RT} \quad \text{(Arrhenius)}$$

$p = 1$ since the only gas used was oxygen

$R = 4.575$ (gas constant)

$T = 245°\mathrm{C},\ 518°\mathrm{K}$

$$3.58 = b - \frac{E}{2360}$$

Air

Crossing point of air and furnace curves was 12.2 mv. This is equivalent to 293° C or 566° K.

The tangent to the air curve at the point of intersection was determined as follows:

At the 19-minute ordinate	16.0 mv	390° C
At the 9-minute ordinate	6.0 mv	147° C
		243° C

Tangent of α = 24.3 (air)

$T = 293^\circ C,\ 566^\circ K$

Concentration of oxygen in air = 0.209

$$\frac{1}{p} = 4.78$$

$$\text{Ln } (4.78)(24.3) = b - \frac{E}{2580}$$

$$4.75 = b - \frac{E}{2580}$$

Solving for E and b

$$4.75 = b - \frac{E}{2580}$$

$$3.58 = b - \frac{E}{2360}$$

$$1.17 = \frac{E}{2360} - \frac{E}{2580} \quad \text{(by subtraction)}$$

$$3000 = 0.093\ E$$

$$E = 32,200$$

Substituting this value in the oxygen equation:

$$3.58 = b - \frac{32,200}{2360} = b - 13.65$$

$$b = 10.07$$

Solving for T_{15}

Where tan α = 15.0 in oxygen (T_{15})

$$\text{Ln } 15.0 = 2.71 = 10.07 - \frac{32,200}{4.575\,T} = 10.07 - \frac{7050}{T}$$

$$7.90 = \frac{7070}{T}$$

$$T = 860^\circ K \text{ or } 585^\circ C$$

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Appendix XI-A

HIGH SULFUR COMBUSTOR STUDY
500,000 LB/HR STEAM GENERATOR
CONCEPTUAL DESIGN
PLANT - UNLOCATED

FOSTER WHEELER CORPORATION
CONTRACT NO. 0-59-1177

CHEMICO CORPORATION
CONTRACT NO. 0067C

FOSTER WHEELER CORPORATION
110 SOUTH ORANGE AVENUE, LIVINGSTON, N. J.

Form 276-60

PROPOSAL AND SPECIFICATION

To Chemico

Date July 1970

The Corporation proposes the equipment listed below to be used in accordance with the fuel specifications hereinafter set forth.

General arrangement, principal dimensions and design of the steam generator unit will be as shown on the proposal drawing identified on the Summary Performance Sheet herein. The principal features of the equipment are stated in general terms throughout the proposal and the specific details not fully described will conform to the Corporation's Engineering Standard.

One natural circulation steam generator unit designed for outdoor service to deliver 500,000 pounds of steam per hour continuously at normal rated load at a pressure of 900 psig and temperature of 825°F at the superheater outlet. The unit will be fired with pulverized coal, pyrite blend containing 77% FeS_2, designed for pressurized furnace operation and will include the equipment as tabulated below and described hereinafter.

Description of conceptual design is presented in a proposal form for comparison purposes. This should not be interpreted as a bonifide proposal or bid price. The proposal is subject to reevaluation at the time a tender is submitted based on the fuel specifications provided.

SUMMARY PERFORMANCE SHEET — PART ONE

Purchaser Chemico

Location Unlocated

Date July 1970

Design pressure 1050

Dwg. No.

Fuel Coal and Pyrites Load	100%					
Steam M lb/hr	500					
Pressure superheater outlet psig	900					
Temperature steam superheater outlet F	825					
Pressure boiler drum psig	975					
Reheat steam M lb/hr	-					
Temperature steam entering reheater F	-					
Temperature steam leaving reheater F	-					
Pressure steam entering reheater psig	-					
Pressure steam leaving reheater psig	-					
Temp feed entering unit F	300					
Temp feed leaving econ. F	None					
Temp air entering unit F	80°					
Temp air leaving air heater F	556					
Temp gas leaving furnace F	2000					
Temp gas leaving boiler F	900					
Temp gas leaving economizer F	-					
Temp gas leaving air heater F	496					
Ditto corrected for leakage F	-					
Excess air leaving %	25					
Wet gas entering air heater M lb/hr						
Wet gas leaving air heater M lb/hr	895					
Air entering air heater M lb/hr						
Air leaving air heater M lb/hr	799					
Draft in furnace in. H_2O	8.6					
Gas side loss thru boiler in. H_2O	.54					
Gas side loss thru suphtr. in. H_2O	.12					
Gas side loss thru economizer in. H_2O	None					
Gas side loss thru airheater in. H_2O	4.75					
Gas side loss thru flues in. H_2O	.31					
Gas side loss thru dust collector in. H_2O	2.90					
Air side loss thru air heater in. H_2O	3.35					
Air side loss thru ducts in. H_2O	1.3					
Air side loss thru burners in. H_2O	5.0					
Air side loss, Sec. Total in. H_2O	9.9					
Air side loss, in. H_2O						
Air & gas loss total in. H_2O	18.5					
Pressure loss to psi	-					
Fuel burned M lb/hr or cfm	.38					
Liberation Btu/hr/cu ft total vol.	16900					
Furn. Cooling Factor net Btu/hr/sq. ft.						
Unit efficiency %	81.2					

SUMMARY PERFORMANCE SHEET - PART TWO

Purchaser Chemico

Location Unlocated

Date

Fuel Coal and Pyrites						
Steam M lb/hr.	500					
Heat Losses.						
Dry gas %	11.8					
Hydrogen and moisture in fuel %	3.6					
Moisture in air %	.26					
Unburned combustible %	1.29					
Radiation %	.38					
Unaccounted for and mfrs. margin %	1.5					
Total losses %	18.85					
Efficiency %	81.2					

Performance based on fuel specified below:

Kind	Coal and Pyrites		
	77% FeS_2 Blend		
Grindability (Hardgrove)	65		
Maximum moisture %	6.0%		
Surface Moisture %	-		
Size	1/4 x 0		
Gas press. at burner	-		
PROXIMATE ANALYSIS	As Received	Moisture Free	Moist. and Ash Free
Moisture	6.0	-	-
Volatile matter	21.2	22.5	28.0
Fixed carbon	15.0/39.0	16.0/41.5	20.0/52.0
Ash	18.8	20	-
Softening temperature of ash	2450		
ULTIMATE ANALYSIS	As Received	Moisture Free	Moist. and Ash Free
Per cent by Weight			
Ash	18.8	20	-
S	0.3	0.3	0.4
H_2	0.9	1.0	1.2
C	13.5	14.4	18.0
CH_4	-	-	-
C_2H_4	-	-	-
C_2H_6	-	-	-
CO	-	-	-
CO_2	-	-	-
H_2O	6.0	-	-
N_2	0.5	0.5	0.6
O_2	2.0	2.2	2.8
FeS_2	58.0	61.0	77.0
Btu/lb ~~as fired~~ Ash Free	5,530		
Btu/cu ft at 60 F-30" Hg			

HEATING SURFACE

Each unit will include the following nominal heating surfaces:

Convection boiler surface	16,290	sq ft
Water walls in furnace	8,180	sq ft
Radiant superheater	None	sq ft
Convection superheater	8,300	sq ft
Reheater I.	None	sq ft
Reheater II.	None	sq ft
Economizer	None	sq ft
Air heater	36,000	sq ft
Total furnace volume	45,200	cu ft
Total furnace surface	8,190	sq ft

Boiler and water wall heating surface consists of all of the heat-transfer apparatus in contact internally with the water or wet steam being heated and externally with gas or refractory being cooled, in which the fluid being heated forms part of the circulating system. This surface is measured on the side receiving heat.

Water wall heating surface in the furnace, including walls, floor, roof, partition walls and platens, consisting of bare or covered tubes, is measured as the sum of the projected areas of the extended metallic surface on the furnace side.

Continuation of water wall tubes beyond the furnace gas outlet is included as boiler heating surface and this surface is measured on that portion of the circumferential and the extended metallic surface receiving heat.

All other boiler surfaces, including screen tubes, are measured on that portion of the circumferential and the extended metallic surface receiving heat. Surface is not included in more than one category.

Superheater and reheater heating surface consists of all of the heat-transfer apparatus in contact internally with steam being heated and externally with gas or refractory being cooled. This surface is measured on the side receiving heat.

Radiant superheater or radiant reheater surface in the furnace, including walls, floor, roof, partition walls and platens, is measured as the sum of the projected areas of the tubes and the extended metallic surface receiving heat.

Continuation of superheater tubes beyond the furnace gas outlet is included as convection superheater surface and this surface is measured on that portion of the circumferential and the extended metallic surface receiving heat.

All other superheater and reheater surface, including screen tubes, is measured on the basis of the circumferential and the extended metallic surface receiving heat.

Furnace cooling factor is the heat available per sq ft of heat absorbing surface in the furnace.

Furnace surface is the projected area of tubes and extended metallic surfaces on the furnace side including walls, floor, roof, partition walls, and platens and the area of the plane of the furnace exit which is defined as the entrance to the convection tube bank.

DESIGN AND CONSTRUCTION
NATURAL CIRCULATION STEAM GENERATORS

All the pressure parts for the steam generator will be fabricated from materials with analyses and thicknesses that shall meet with all the requirements of the ASME Boiler Code.

All welded drum and headers seams will be X-rayed and stress relieved in accordance with the ASME code.

The material surfaces of all drums and headers will be cleaned in the shops by shot blasting.

All nozzles will be forged steel and welded to their drums or headers.

The Steam Generator will be furnished with the following drums:

One (1) 66" I.D. Steam Drum 22'-0" Between Welds SA-212B Material.
One (1) 42" I.D. Mud Drum 22'-0" Between Seam Welds Material, SA-212B.

DRUM INTERNALS

Efficient drum internals have two essential functions. One is the separation of steam from water in order that the downcomer system will be provided with the de-steamed water necessary for proper and safe circulation. The other is the separation of moisture from steam to provide high steam purity. The Foster Wheeler drum internals are devised to effectively provide both functions by means of two stages of separation, the first of which operates to provide steam free water to the boiler circulating system, while the second extracts the last traces of water and impurities from the steam delivered. The internals, illustrated on the preceding page, consist of horizontal centrifugal separators located along the side of the drum and unit chevron drier assemblies arranged along the top of the drum.

The total circulating mixture of steam and water from the boiler tubes is directed by means of girth baffles into the horizontal centrifugal separators. The curved path therein causes separation of steam and water, the steam leaving the separator at both sides through orifices, and the water leaving at the bottom through specially constructed drains.

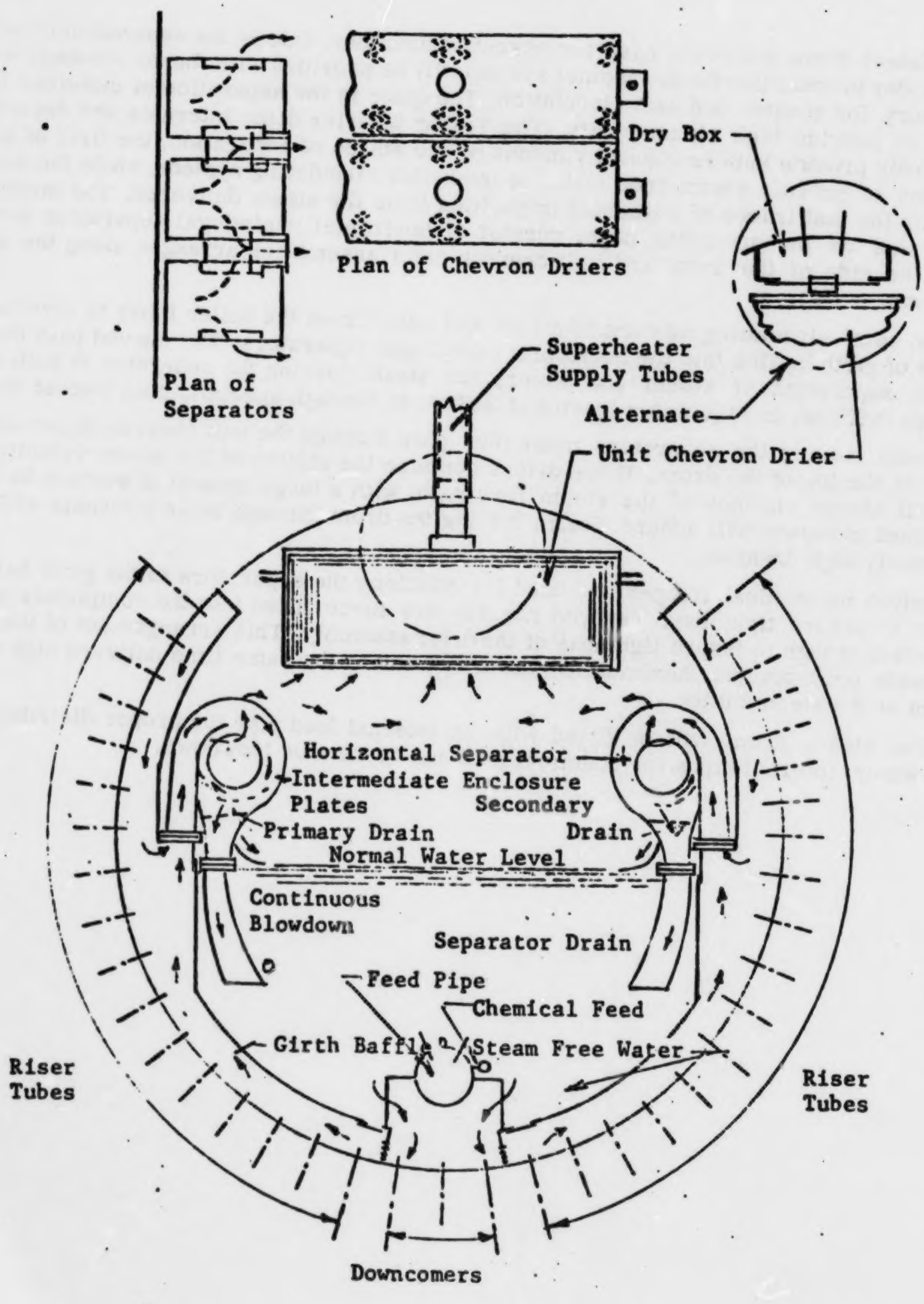
Steam leaving the separators must then pass through the unit chevron drier assemblies at the top of the drum. These driers combine the effects of low steam velocity, and several abrupt changes of the steam flow path, with a large amount of surface to which entrained moisture will adhere. Steam leaving the drum through these internals will have extremely high dryness.

Bolted mechanical flanges are used for attaching the separators to the girth baffle in order to assure tightness. Tapered nozzles are force fitted into the completely welded collection trough to insure tightness of the drier assembly. This arrangement of the drum internals provides the maximum accessability and at the same time delivers high purity steam at the steam outlet.

The steam drum will be fitted with an internal feed pipe for proper distribution of feed water, internal pipes for chemical feed and continuous blowdown.

DRUM INTERNALS

TWO ROWS OF SEPARATORS


Plan of Separators
Plan of Chevron Driers
Dry Box
Superheater Supply Tubes
Alternate
Unit Chevron Drier
Horizontal Separator
Intermediate Enclosure Plates
Secondary Drain
Primary Drain
Normal Water Level
Continuous Blowdown
Separator Drain
Feed Pipe
Chemical Feed
Girth Baffle
Steam Free Water
Riser Tubes
Riser Tubes
Downcomers

FURNACE

The furnace shall be of **Foster Wheeler Monowall Construction** and shall consist of welded fin-tube panels.

Tubes will be secured to headers by welding and to drums by welding Tubes will be seamless or resistance welded material. Thickness of tubes, headers, risers and downcomers will be in accordance with ASME Boiler Code rating for the material used.

All material required by the design will be furnished by the Corporation, including welded wall panels, supports, risers, downcomers, closure bars and all material required for providing a sound structure and proper circulation.

DESIGN DATA

Circuit or Wall	Tube O. D.	Tube Spacing	Material	Number
Front	3"	3-3/4" Finned	Carbon Steel	
Rear	3"	3-3/4" Finned	Carbon Steel	
Side (Each)	3"	3-3/4" Finned	Carbon Steel	

Downcomers, headers and riser tubes will be adequately sized and numbered to assure proper circulation.

BOILER SECTION

Construction - Boiler elements, will be of suitable material and thickness for the pressure and temperature encountered and in accordance with the ASME Boiler Code. Joints between the elements and drum stubs shall be secured by welding.

Boiler heating surface is stated on heating surface sheet herein.

Boiler Section Arrangement - Vertical, inline tube bundle terminated on on one end by a 42" I.D. Mud Drum and the other end a 66" I.D. steam drum.

Number of rows wide: 44 tubes on 6" centers

Number of rows deep: 28 tubes on 4" centers

Length of elements: Distance between drums - center lines 20'

Tubes:

Number - 1232

Diameter - 2" O.D. x 1.750" I.D.

Material - SA-210

SUPERHEATER SPECIFICATIONS

CONSTRUCTION Superheater elements, headers, connections and spacers will be of suitable material and thickness for the pressure and temperature encountered and in accordance with the ASME Boiler Code. Joints between the elements and the headers shall be secured by welding.

EQUIPMENT INCLUDED All superheater elements and headers, complete with required steam connections to drum, element spacers, immediately adjacent supports or hangers, and thermometer or thermocouple well at superheater outlet.

Superheater outlet connection outside of setting.
Safety Valves, drain and vent connections as required by the design.

Superheater heating surface is stated on Heating Surface Sheet herein.

DESIGN DATA

Superheater Section	Pendent	Pendent	Pendent	
Location in Unit	Furnace	HRA	HRA	
Design Pressure	1100 psig	1100 psig	1100 psig	
No. of Sections Wide	-	-	-	
No. of Loops	1	1	3	
No. of Tube Elements per loop	8	4	2	
No. of Rows Deep	11	22	44	
Tubes: Number	88	88	88	
Diameter	2-1/4" x 1.75	2-1/4" x 1.90	2-1/4" x 1.9	
Material	SA-213 T22	SA-213 T11	SA-213-T11	
Tube Spacing:				
Transverse:	24"	12"	6"	
Front to Back:	3-3/4"	5"	5"	
Inlet Headers				
Number:	1	-	1	
Diameter O.D.xI.D.	12.75x11.626	-	12.75x11.626	
Material	SA-212 B	-	SA-212 B	
Inlet Transfer Pipe:				
Number	-	22	22	
Diameter O.D.xI.D.	-	5"x4.50"	5"x4.50"	
Material	-	SA-210	SA-210	
Location	-	Header Transfer Drum to Inlet Header Pipe		
Outlet Headers:				
Number	1	1	-	
Diameter O.D.xI.D.	12.75 x11.626	12.75x11.626	-	
Material	SA-212 B	SA-212 B		
Outlet Connections:				
Number				
Diameter	-	-	-	
Material				
Location				

STEAM GENERATOR ACCESSORIES

The accessories for each steam generator will be suitable for the design pressure and will be selected by the Corporation from the products of the manufacturers listed elsewhere in this proposal under "List of Approved Manufacturers."
Accessories to be furnished will be as listed below:

WATER COLUMN AND GAGE Two (2) diamond, MP-3000 15" vision multi-port bi-color gage glasses, complete with support tube assemblies, illuminators, and one floor stand with required number of mirrors.

SAFETY VALVES AND NOZZLES

No.	Size (Inches)		Manufacture	Cat. No.
2	3	Safety valves Drum	Consolidated	1738 A
		Safety valves		
1	2	Safety valves, superheater	Consolidated	1738 D
		Safety valves, reheater		
		Safety valves, reheater		

OTHER ACCESSORIES AND NOZZLES

1	8	Feed valve	Edward	7594 Y
1	8	Check valve	Edward	7594 Y
1	1-1/2	Continuous blow-off valve	Edward	3624
1	1-1/2	Vent valve	Edward	3624
1	1	Chemical feed valve	Edward	3624
1	1/2	Steam gage	Crosby	-
1	1/2	Test gage valve	Edward	3624
1	1	Steam Gage Shut-off Valve	Edward	3624
2	1	Water column drain valve	Edward	3624
2	1/2	Gage glass drain valve	Edward	3624
4	1-1/2	Gage glass shut-off valve	Edward	3624
10	1-1/2	Water Wall Drain Valves	Edward	3624
2	3/4	Superheater Outlet Vent Valves	Edward	3624

The Corporation will also furnish nozzles for all required auxiliary connections.

The Corporation will furnish the headers and connections of each steam generator with the number of thermowells it considers adequate for the installation. These will be made according to the Corporation's design and fabrication standards. Additional wells or changes of well design will be furnished upon request and at the Purchaser's expense.

REGENERATIVE AIR HEATER

EQUIPMENT INCLUDED

Regenerative type air heater as manufactured by the air preheater , will be as follows:

Total heating surface of air heater for one steam generator is stated on Summary Performance Sheet herein.

Number of air heaters for one steam generator one (1)

Each air heater will be size 23 HR-3 1-1/2 and equipped with the following:

All driving mechanism including speed reducer and electric motor.

12" cold end layer of heating elements made of corrosion-resistant, low-alloy steel mounted in baskets for side removal.

Hot end layer of heating elements mounted in baskets.

Cleaning device including electric motor and steam piping, valves and fittings to the device.

Insulation anchorages.

Four (4) 20" x 20" access doors.

EQUIPMENT NOT INCLUDED

Electrical connections and starters for driving motors.

Piping and valves for water lines to and from bearing cooling water connections.

FLUES AND DUCTS

Flues and ducts will be of welded steel plate construction. Small sections which can be conveniently shop assembled will be so fabricated. Large sections will be sized for field assembly. All parts will be properly supported, stiffened and made commercially tight. Expansion joints and access doors will be provided where necessary. The ends of flues or ducts will be flanged and drilled for bolting to connecting equipment, or arranged for welding.

The Corporation will furnish only the flues and ducts listed in the following tabulation. Underground flues and ducts will be furnished by the Purchaser as part of the foundations. Hanger and bracket supports, if required for attachment to structural steel, are included.

FLUES	METAL THICKNESS
Economizer to Air Heater	3/16"
Air Heater to Dust Collector	3/16"
DUCTS	
I.D. Fans to Air Heater	3/16"
Air Heat to Windbox	3/16"
Windbox	1/4"
SOOT HOPPERS	
Under the Mud Drum	1/4"

INSULATION AND OUTER FINISH

The enclosure for the furnace and convection pass will consist essentially of continuously welded fins between adjacent tubes of all peripheral walls, backed by insulation.

The roof of the furnace and the convection pass will be formed by tubular surface, with the integral fins continuously welded to adjacent tubes.

Where transition will occur between the integral fin type tube walls and plate type seals, the transition will be made by scalloped bars.

All castable refractories and special shapes, as required by the design, will be furnished.

The outer surface of the unit will be furnished as described.

Doors for access and inspection will be furnished as required by the design.

Insulation and outer finish materials, for each unit, will be in accordance with the tabulation below:

AREA OR LOCATION	THICKNESS IN INCHES			
	*Insulating Block	Mineral Wool Blanket	Insulating Cement	OTHER MATERIALS

*Insulating block will be , or equal.

PULVERIZER SELECTION AND PERFORMANCE

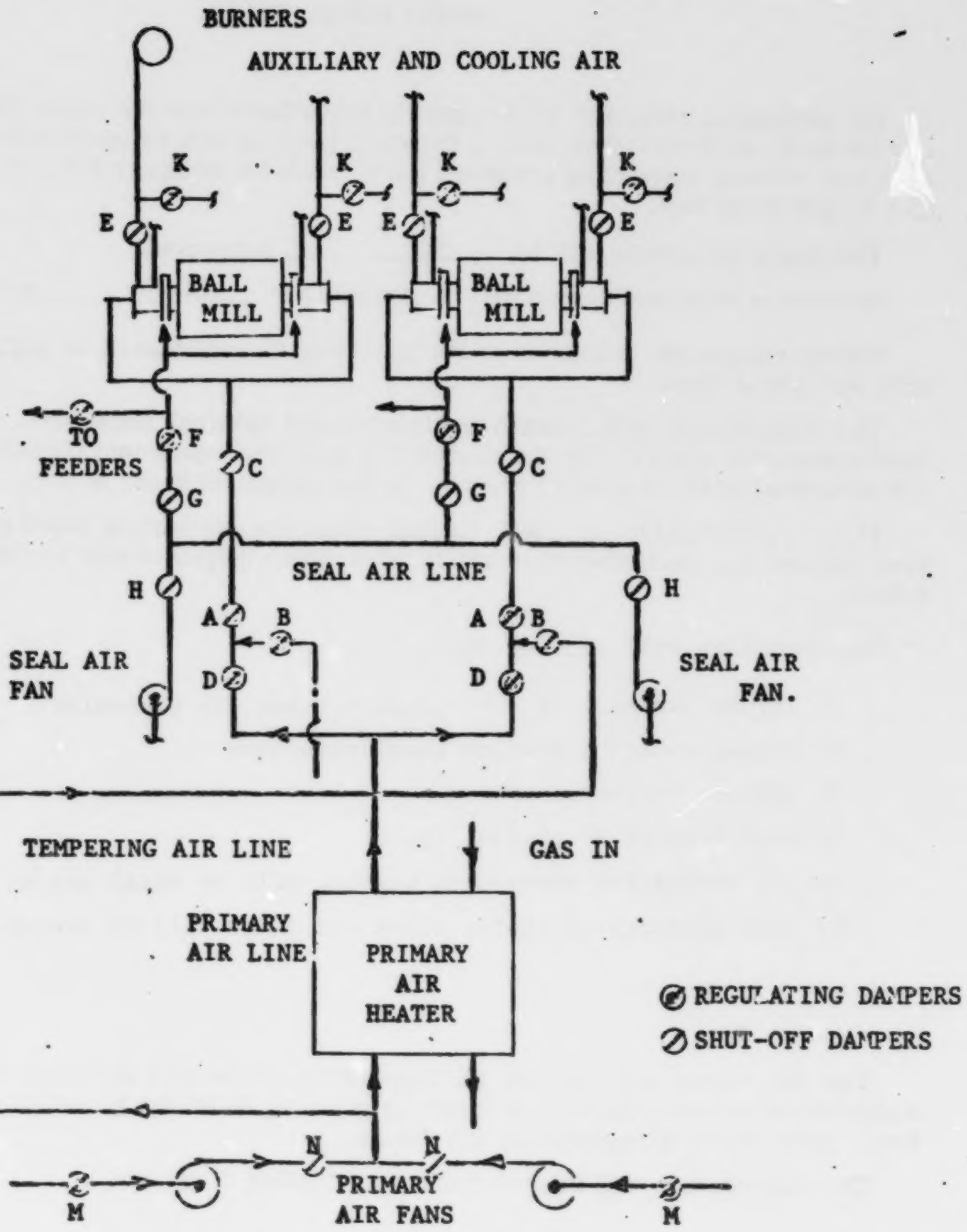
Selection of Pulverizer equipment and the performance stated below are based on the condition that the general arrangement of equipment furnished by the Corporation shall be not less favorable than indicated on drawing . The equipment shall have been erected in accordance with the Corporation's plans and specifications, is in operating condition satisfactory to the Corporation and is properly maintained and operated by the Purchaser. Fuel characteristics shall not be less favorable than indicated by the analyses listed. The Corporation will limit its guarantees to those items of performance specifically listed below under "Guarantee".

MILL SELECTION – Number, Type and Size: Two (2) D8-C, Ball-Tube

Item		Mill Performance			Basis of Mill Selection	
Fuel Specification: (As Fired)						
Type		Coal Pyrite Blend, 77% FeS_2			Same	
HHV	BTU/lb	5530			5530	
Grindability	(HGU)	70			70	
(1) Total Moisture	%	6%			6	
Surface Moisture	%	–			–	
Feed size		3/8" x 0			3/8" x 0	
(2) Steam Flow –	M lbs/hr			500,000	500,000	
Total Fuel Burned	lbs/hr			138,000	138,000	
Number of mills in operation:				2	2	
Fuel per Mill –	lbs/hr			69,000	69,000	
Fineness:						
% through #200 USS mesh:				90	90	
% through #50 USS mesh:				99	99	
Total HP for all Mills, Fans and Feeders in operation:				930	930	
Total HP per Mill, with Fans and Feeder:				465	465	
Corresponding KW per Mill: Based on 90% Motor Efficiency:				380	380	
KW per ton of fuel fired:						

(1) Coal blend thermally pre-dried at coal cleaning plant allowance made for 6% moisture.

(2) Design for full load operations only.


BURNERS
AUXILIARY AND COOLING AIR
K
K
K
K
E
E
E
E
BALL MILL
BALL MILL
TO FEEDERS
F
F
C
C
G
G
SEAL AIR LINE
H
H
A
B
A
B
D
D
SEAL AIR FAN
SEAL AIR FAN.
TEMPERING AIR LINE
GAS IN
PRIMARY AIR LINE
PRIMARY AIR HEATER
REGULATING DAMPERS
SHUT-OFF DAMPERS
N
N
M
M
PRIMARY AIR FANS

STRUCTURAL STEEL

All structural steel will be designed in accordance with the latest Rules of the American Institute of Steel Construction. Diagonal bracing will be used where lateral loads are involved. Beams supporting pressure parts shall be designed for a maximum deflection of 1/2 inch in 10 feet.

The steam generator will be top supported.

Structural steel and casing will be suitable for outdoor service.

Firing equipment, if located at the operating elevation, will be supported on Purchaser's structural steel.

The Corporation will furnish horizontal and vertical buckstays, and all hangers and spring supports required by the design, for all other equipment included in this proposal. All steelwork shall be painted one coat before shipment from factory.

The Corporation will furnish complete supporting steel structure, including base plates. No load other than steam generator equipment will be carried unless stated below:

The structure will provide for:

1) lateral support of dust collector and air preheater
2) piping within 5 feet of steel structure
3) seismic factor of .048
4) wind load of 30 lbs/sq. in.
5) all insulation exposed to weather will be metal lagged
6) flat surfaces of casing flues and ducts will be sloped for drainage.

The Purchaser will furnish all foundations. If the unit is bottom supported, the foundation shall include concrete or masonry piers up to steam generator wall support members, or headers, if required by the design.

The Corporation will furnish foundation loading diagrams.

BURNERS

EQUIPMENT INCLUDED

Burner equipment and burner windbox will be as described below:

Burner windbox will be of welded steel plate construction. All parts will be properly supported, stiffened and made commercially tight. Provision will be made for support of the burners.

Burners will be:

As manufactured by Foster Wheeler

Type Anthracite Double Cyclone

Number 8

Suitable for Pyrite, Coal Blends (77% FeS_2)

Burner equipment will include the following:

Forced draft fronts and intergral air control dampers.

Eight (8) Foster Wheeler anthracite double cyclone burners, (30" dia.) illustrated on following page.

Eight (8) automatic air atomizing light oil-electric retractable ignitors operated by remote control, type 101R as manufactured by the Engineer Company or equal, each ignitor includes atomizer gun with gun support bronze hose, shut-off valves, pressure gauges and ignition transformer mounted in enclosure unit which will be mounted on the boiler. A separate manual ignitor panel will be furnished for each ignitor.

Note: No flame scanning or proving equipment is included in this proposal.

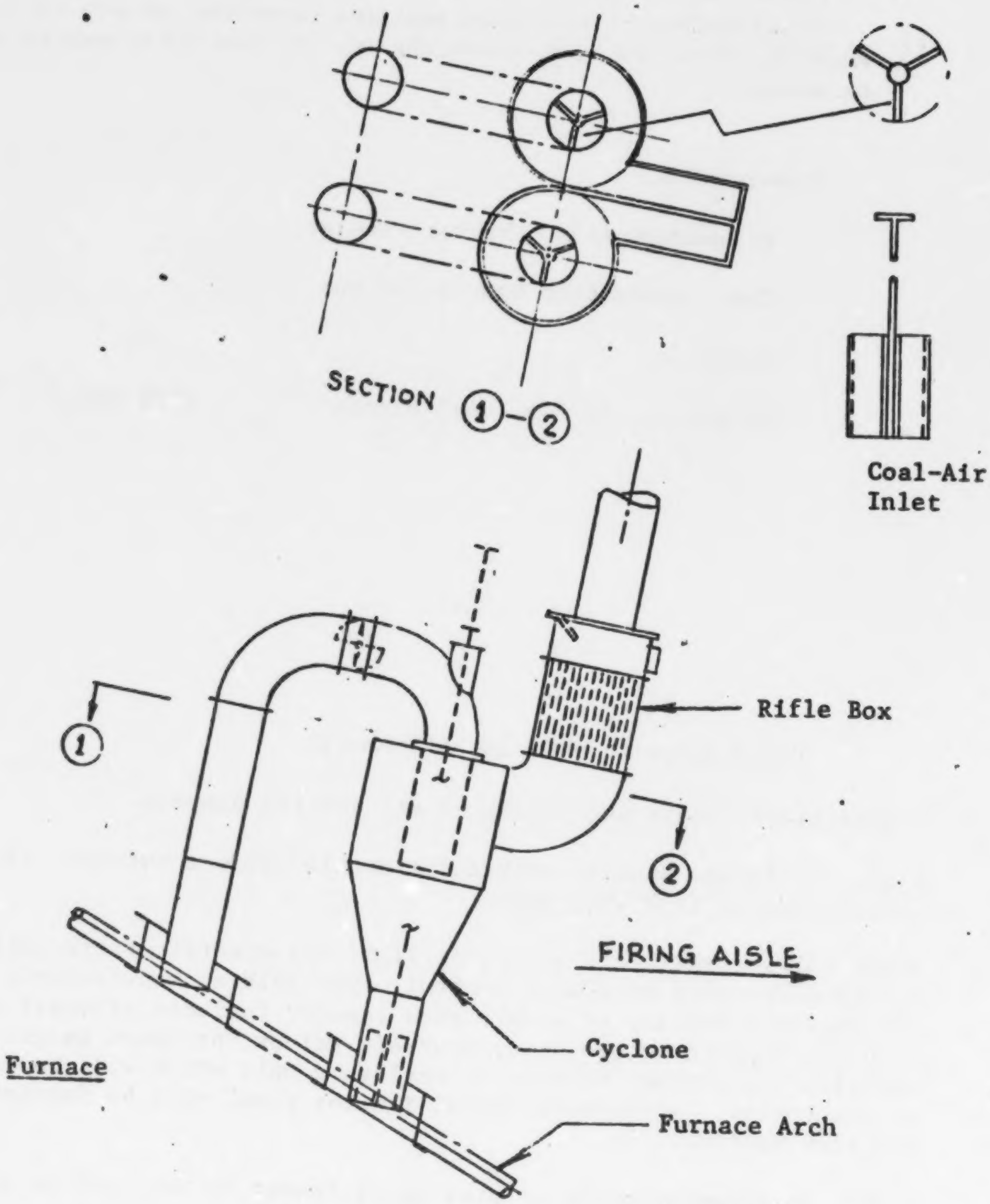

SECTION ①-②
Coal-Air Inlet
Rifle Box
①
②
FIRING AISLE
Cyclone
Furnace
Furnace Arch

Figure ILLUSTRATION OF A TYPICAL FOSTER WHEELER ANTHRACITY TYPE BURNER

SOOT BLOWERS

The Corporation will furnish soot blowing equipment as described below.
Soot blowers will be manufactured by:
The soot blowing system will blow with Steam at 850 psi
Soot blowers, pipe, valves and fitting will be suitable for 1050 psi.

Type of drive and method of operation:

Electric motor operated, automatic sequential type with operating panel for mounting on purchaser's control board. All starters shall be mounted as individual units on blowers

Soot Blower Descriptive Data:

No.	Type	Length or length of travel	Location
8	FULL RETRACT	11"	SUPERHEATER PASSES AND BOILER SECTION
4	WALL DESLAGGER		FURNACE
4	AIR HEATER		AIR HEATER

Element material will be as required by the service.

Pipe, Valves and Fittings to be furnished by

Items	Air or Steam	Function	Terminal Points

Air supply if required will be furnished by Purchaser.

Piping 2" and under, if furnished by the Corporation, will be supplied in random lengths and shall be fitted in the field by the erection contractor. Diagram showing location of expansion loops and fixed supports will be provided by the Corporation.

If electrical drives and controls are supplied for soot blowers, all equipment will be shop wired to terminal blocks and all electrical wiring and switches external to the equipment will be furnished by the Purchaser.

CONTROLS: Electric Accessories

12 REVERSING STARTERS
12 NON-REVERSING STARTERS

EQUIPMENT, MATERIAL AND SCOPE OF WORK

AUTOMATIC SEQUENTIAL - STEAM BLOWING - ELECTRIC MOTOR DRIVEN, ELECTRICALLY CONTROLLED SOOT BLOWER SYSTEM

---

8 - Model IK-525 Long Retractable Blowers with approximate coverage of 22' 0". Each long retractable unit includes the following:

A. Series 900 Carbon Steel Construction.
B. 1-1/2 H.P. 460 volt, 3 phase, 60 hertz Electric Motor attached to the moveable carriage.
C. Totally enclosed and sealed carriage assembly to contain a completely geared drive mechanism.
D. "Self-locking" geared drive to prevent lance tube from becoming self-propelled when operating power is not applied.
E. Quick disconnect plug in power voltage conductors to blower motor.
F. Mechanically operated poppet type blowing medium valve with adjustable pressure control and stellited valve seat.
G. Positive Pressure Wallbox.

5 - Model IR3 short retractable wall blowers equipped as follows:

A. Series 900 Carbon Steel Construction.
B. Fixed position 1/6 H.P. TENV Electric Motor.
C. Mechanically operated poppet type valve with adjustable pressure control.
D. Flexible valve seat and disc with stellited seat trim and stainless steel disc.
E. Positive Pressure Wallbox

1 - Set of Air Heater control mechanism and mounting bracket to include the following:

a. 1-1/2" DIAMOND Series 600# steam admission valve.
b. Components required for remote operation of the air preheater cleaning device.
c. Electric motor to be furnished by others.

1 - DIAMOND SELECTRONIC all silicon, solid state soot blower control panel, insert type with self contained enclosure for operation of the boiler cleaning system from the control room. The cleaning system control panel will provide for the following:

A. Master control enclosure to contain a power supply, all control components mounted on plug-in type module boards, selector switches for each of 14 units, alarm devices and enunciator lights for each of the following functions:

1. Control voltage
2. Auto or continuous operation of steam valve
3. IK motor overload.
4. Low blowing medium pressure.
5. IK forward travel
6. IK reverse travel
7. Sequence finish

B. Ammeter to indicate motor current.

C. Elapse timer alarm

D. Graphic boiler diagram

E. Unit indicating lights at each soot blower location

ELECTRICAL ACCESSORIES

Master Reversing Starter System with individual Non-Reversing starters mounted on blower.

1 - Master Reversing Starter, Size "1" NEMA 3
8 - Non-Reversing Starters, Size "O" NEMA 3 - IK
5 - Non-Reversing Starters, Size "OO" NEMA 3 - IR
1 - Non-Reversing Starter Size "OO" NEMA 3 - APC *
14 - Joy Manufacturing Co. Heavy Duty Push Buttons, NEMA 4, one each to be mounted and wired per blower.

*for mounting by others

PIPE, VALVES & FITTINGS

All piping is furnished in random lengths for fabrication in the field. Piping drawings will be furnished to show general routing of soot blower piping and to assist the designer and erector in providing an adequate supply of blowing medium, proper piping drainage, and to show need for supports, guides, and hangers. Final routing of piping is the responsibility of others.

Thermal and mechanical stresses on the piping systems will be considered to the extent of providing schematic information, to indicate the need for expansion provisions.

1 - 2" emergency stop valve
1 - 2" Fisher automatic main line valve type 655 AQR 600# WC6 body
1 - 2" main line

13 - 2" branch lines
1 - 1-1/4" Trap and Strainer
1 - 1-1/2" Main Line - APC
1 - 1-1/2" Branch line - APC
2 - 3/4" Traps and Strainers - APC
9 - 3/4" Bypass valves
1 - Set drawings

Pipe supports, guides and hangers as required.

TO BE PROVIDED BY OTHERS

a. Support plates and sleeves to attach blowers to boiler and furnace walls.

b. Structural supports for IK Units.

c. Source of suitable electric current, as stated in quotation.

d. Electric wiring to interconnect blowers, panel, push button stations, motor starters, and source of electric current.

e. Labor, supervision, scaffolding, rigging and other costs incidental to installation of proposed boiler cleaning equipment.

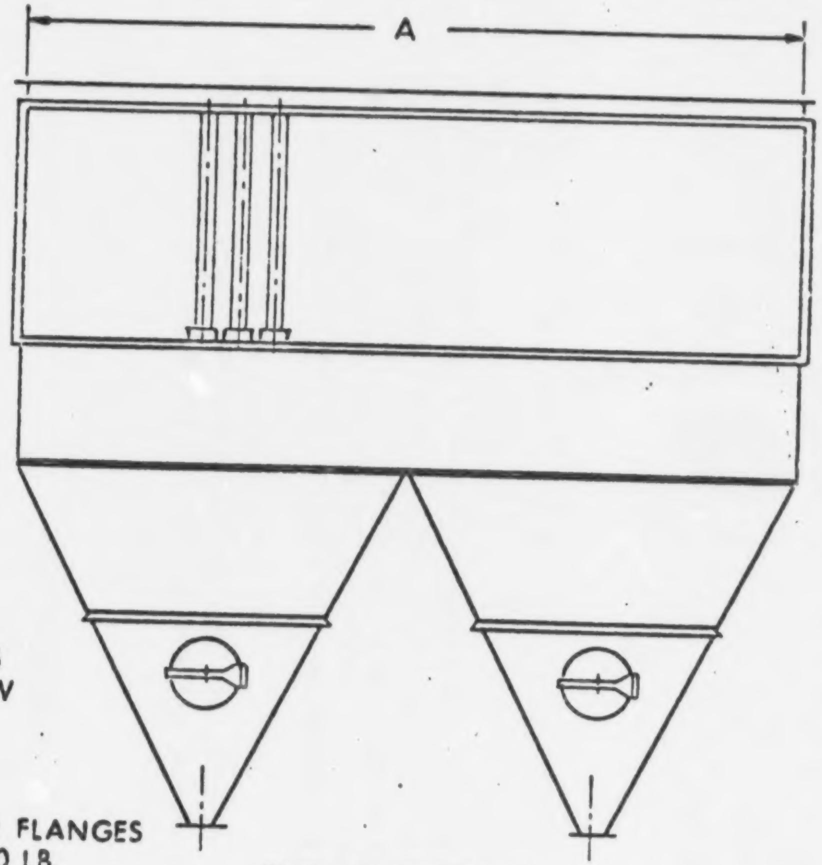
f. Sealing and aspirating air piping from source of supply to individual blower pressure seals.

DUST COLLECTOR

The Corporation will furnish one (1) mechanical dust collector Type 104 BWHS-17-357 manufactured by UOP Air Correction Division or equipment as described on following pages.

The dust collector will be of the mechanical type designed for an overall efficiency of 83% on the basis of a flyash analysis with not more than 30% less than 10 microns in size. The maximum loss through the collector at 500,000 lb/hr boiler capacity will not exceed 2.9" H_2O. The hopper capacity will be sufficient for hour ash storage with an ash density of lb/cu. ft.

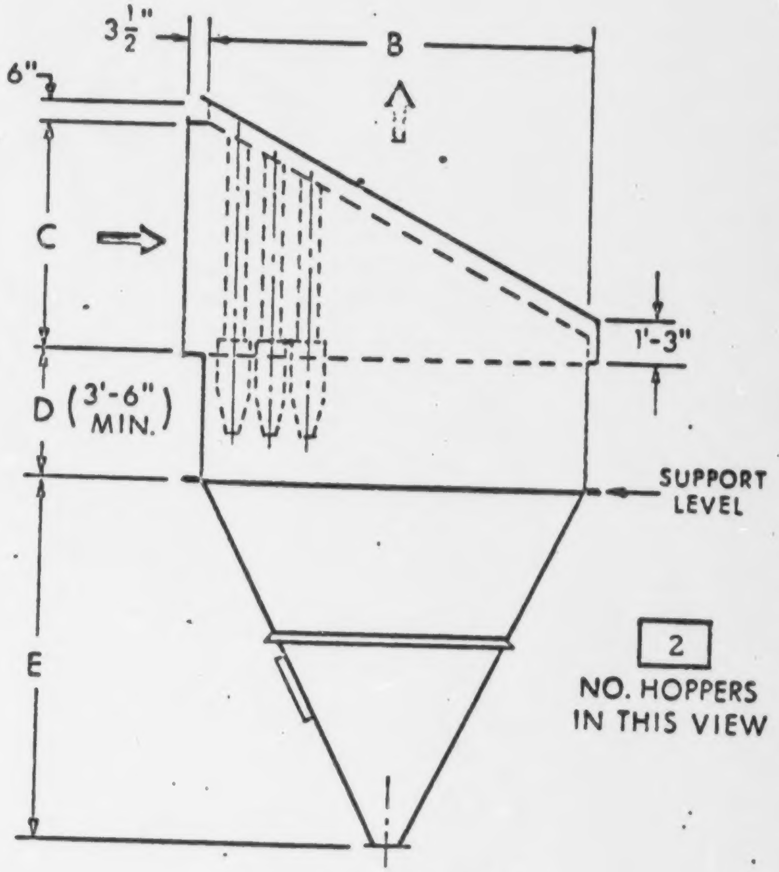
SIDE INLET – TOP OUTLET



3
NO. HOPPERS
IN THIS VIEW

NOTE:
STD. HOPPER FLANGES
MATCH 8" 150 LB.
ASA DRILLING

END ELEVATION



2
NO. HOPPERS
IN THIS VIEW

SIDE ELEVATION

DESIGNATION	DIMENSIONS (FEET & INCHES)					WEIGHT		DUST·CAP.
DESIGN	A	B	C	D	E	WITHOUT DUST LOAD	WITH DUST LOAD	CU. FT.
104BWHS-17-357	22-0	17-8	10-3	3-6	8-1	66,000		1110

NOT FOR CONSTRUCTION – DIMENSIONS APPROXIMATE ONLY

COLLECTOR SUPPORTS MOUNTED ON CASING, SUPPLIED BY MANUFACTURER
STRUCTURAL STEEL, ON WHICH COLLECTOR SUPPORTS REST, SUPPLIED BY OTHERS

AIR CORRECTION
DIVISION

DESIGN 100 SERIES TUBULAR DUST COLLECTOR
DIMENSION SKETCH

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BY:	DATE:	FILE:	SK. NO. [illegible]-1359-C

FORM NO. 5-062

TERMINAL POINTS - PART I

The equipment furnished by the Corporation will terminate at the following points beyond which connections and equipment are to be furnished by the Purchaser:

Major Pressure Part Terminal Points:	Number	Size		Arrangement
Superheater Outlet	1	12.75"		Single ended
Reheater #1 Inlet	--	--	--	--
" #1 Outlet	--	--	--	--
Reheater #2 Inlet	--	--	--	--
" #2 Outlet	--	--	--	--
Feedwater Inlet				

1. Superheater Outlet and Economizer Nozzles will terminate immediately outside of the steam generator casing.
2. Safety Valves will terminate at valve discharge flange.
3. Feed stop and check valves will be located in Purchaser's piping.
4. Economizer Hopper will terminate at Outlet Flange.
5. Drain and Sampling Connections will terminate at main operating floor level.
6. Flues and Ducts will terminate at the force draft fan discharge on the air side and at dust collector inlet flange on the gas side.
7. Thermocouples will terminate at common junction boxes adjacent to the boiler casing.
8. Dust Collector Connections will terminate at the flue gas outlet flanges and at the outlet flanges of their hoppers.
9. Sealing Air will be manifolded and piped to F.D. fan.
10. Aspirating Air Piping will termiante in one connection located at basement level.
11. Electrical Equipment will be furnished without wiring or controls, unless specifically described in this proposal.

TERMINAL POINTS - PART II

The equipment furnished by the Corporation will terminate at the following points beyond which connections and equipment are to be furnished by the Purchaser:

A. For Solid Fuel Fired Units:

1. FURNACE HOPPER will terminate at the hopper seal castings.
2. FLY ASH HOPPERS will terminate at the outlet flange.
3. RAW COAL CONNECTION to Purchaser's equipment will be at the feeder inlet.

STEAM GENERATING UNIT PERFORMANCE AND GENERATING CONDITIONS - PART I

Performance data for the equipment covered are submitted and made a part of this proposal in accordance with the recommendations of the American Boiler Manufacturers Association.

It is recognized that the performance of the equipment covered in this proposal cannot be exactly predicted for every possible operating condition. In consequence, any predicted performance data submitted are intended to show probable operating results which may be closely approximated but which cannot be guaranteed except as expressly stated in the guarantee clause or clauses in this proposal.

Any performance curves submitted are for the Purchaser's convenience and the performance indicated thereon is not offered by the Corporation, nor to be construed by the Purchaser, as a proposal or contract obligation.

The general arrangement of equipment furnished by the Corporation, and the general design and arrangement of related equipment furnished by others, shall be not less favorable than indicated on the proposal drawing identified on the Summary Performance Sheet herein.

The equipment shall have been erected in accordance with the Corporation's plans and specifications, properly maintained and operated by the Purchaser, and shall be in operating condition satisfactory to the Corporation. The heat absorbing surfaces shall be clean inside and out.

There shall be sufficient forced and/or induced draft fan capacity available to provide the necessary air for combustion at a pressure at the burner windbox to overcome all of the resistance through the unit including the breeching and stack. Means shall be provided to control the flow of the supply of air and of the flue gases down to minimum ratings.

Ambient air conditions:

Temperature of boiler room air	F	80
Relative humidity of boiler room air	%	60
Barometric pressure	in. hg.	29.921
Weight of water per lb of air	lb.	0.013

The fuel characteristics shall not be less favorable than that indicated for the fuel or fuels listed on the Summary Performance Sheet herein.

Operating conditions shall be as stated on the Summary Performance Sheet herein.

Measurements of CO_2 or other properties of the combustion gases in furnace or convection passes shall be determined by sampling uniformly across the width of the unit. No performance tests shall be made unless combustion equipment and the combustion process are functioning normally.

STEAM GENERATING UNIT PERFORMANCE AND GUARANTEE CONDITIONS - PART II

The condition of the concentrated boiler water shall be as shown in the following table for the applicable operating pressure:

Pressure at Outlet of Steam Generating Unit — psig	Total Solids ppm	Total Alkalinity ppm	Suspended Solids ppm
0 - 300	3500	700	300
301 - 450	3000	600	250
451 - 600	2500	500	150
601 - 750	2000	400	100
751 - 900	1500	300	60
901 - 1000	1250	250	40
1001 - 1500	1000	200	20
1501 - 2000	750	150	10
2001 - and higher	500	100	5

The treatment of feed water and the conditioning of boiler water are beyond the control of the Corporation. Therefore, the Corporation shall not be held responsible for damage due to the presence of oil, grease, scale or deposits on the internal surfaces of the equipment; or for damage resulting from foaming caused by chemical conditions of the water, or for damage resulting from corrosion or caustic embrittlement. The Corporation shall not be responsible for carryover resulting from the presence of oil, grease or other contaminating material.

WATER AND STEAM SAMPLING CONDITIONS

Samples of water for testing shall be taken from the continuous blowdown, or from a suitably located sampling pipe, through a cooling coil to prevent flashing. Sampling and determination of boiler water conditions shall be under the methods contained in ASTM Special Technical Publication No. 148.

Samples of condensed steam for determination of solids shall be obtained in accordance with the method specified in the latest edition of ASTM-D-1066, Tentative Method for Sampling Steam.

Solids in the steam sample may be determined by either of the two methods described below:

If the electrical conductivity determination of dissolved solids in the condensed steam is used, it shall be made in accordance with ASTM-D-1125-59, Tentative Method on Electrical Conductivity of Water. Remove dissolved gases from the sample as completely as possible by mechanical means without contaminating the sample with any added material which will increase its conductivity. The conductivity shall be corrected to compensate for residual ammonia, carbon dioxide or other gases remaining in the sample and the dissolved solids shall be calculated from this corrected conductivity. For measuring performance by the electrical conductivity method, the average of ten determinations made at regular intervals throughout the test period shall be used.

If the gravimetric determination of total solids in the condensed steam is used, it may be made in accordance with Method A of the latest edition of ASTM-D-1069, Tests for Suspended and Dissolved Solids in Industrial Waters, or a similar method embodying the essential principles of that specification. For measuring performance by the gravimetric method, the results shall be expressed as the average of three determinations made upon a composite sample which shall be taken throughout the entire test period.

INSPECTION, TEST AND WARRANTY CONDITIONS

Each steam generator will be built in accordance with ASME Boiler Code for working pressure specified on Summary Performance Sheet herein. The Corporation will furnish the Purchaser with a certificate from an authorized boiler inspection and insurance company stating that the steam generator is safe for the design working pressure specified above and conforms with the ASME Boiler Code. The Corporation will pay for shop inspection.

Field inspection by the insurance company shall be paid for by the Purchaser unless the erection of the equipment is to be performed by the Corporation.

When erection is completed, but before installation of the setting, the steam generator shall be tested and made tight by the erection contractor at an hydrostatic pressure one and a half times design pressure. The Purchaser shall provide the water required for said test and introduce same into the boilers when they are ready for test and shall also provide drainage from blow-off when test has been completed.

When a tightness test is required for the furnace enclosure and the steam generator gas passages, the openings of the unit shall be blanked and air shall be admitted until the internal pressure reaches 20 in. W.G. The unit shall then be sealed and, if the pressure drop does not exceed 5.0 in. W.G. in ten minutes, the unit shall be considered acceptably tight.

Performance tests, if required, and performance calculations shall be in accordance with the applicable Short Test Form in the latest edition of the ASME Test Code for Stationary Steam Generating Units, and the measure of performance shall be the results of such tests. Performance calculations shall be based on the steam tables in the latest edition of "Thermodynamic Properties of Steam" by Keenan and Keyes.

Performance tests, of the steam generator or any of the equipment furnished by the Corporation, if required, shall be run within sixty days after the Purchaser shall have received notice from the Corporation that the equipment furnished is ready for testing, it being understood that the Corporation may require preliminary tests. Tests shall be conducted only on one representative unit mutually agreed upon by the Purchaser and the Corporation. The Purchaser, at his own expense, shall make all preparations, furnish all operating and testing personnel and incur all expenses connected with such tests, and shall give to the Corporation at least fifteen days' notice of the date or dates on which tests will be made.

The Corporation's representative shall have access to the records at all times, and the test shall be conducted in a manner to satisfy the Corporation that the specified performance conditions are being maintained. A complete copy of test data and results shall be furnished to the Corporation.

The equipment shall be considered as accepted if tests show that the guarantees have been fulfilled, or if the Purchaser shall fail to have said equipment tested within period herein specified. In case of failure to meet performance guarantees, the Corporation reserves the right to change or replace the equipment furnished so that guaranteed performance will be obtained.

The Corporation assumes no responsibility for damage to boilers or other equipment furnished by it, resulting from improper operation or introduction of improper substances to their interiors.

Appendix XI-B

HIGH SULFUR COMBUSTOR STUDY
50 MW STEAM GENERATOR
PROTOTYPE
PLANT UNLOCATED

FOSTER WHEELER CORPORATION
CONTRACT NO. 0-59-1177

CHEMICO CORPORATION
CONTRACT NO. 0067C

FOSTER WHEELER CORPORATION
110 SOUTH ORANGE AVENUE, LIVINGSTON, N. J.

Form 276-60

PROPOSAL AND SPECIFICATION

To Chemico

Date July 1970

The Corporation proposes the equipment listed below in accordance with the fuel specifications hereinafter set forth.

General arrangement, principal dimensions and design of the steam generator unit will be shown on the proposal drawing identified on the Summary Performance Sheet herein. The principal features of the equipment are stated in general terms throughout the proposal and the specific details not fully described will conform to the Corporation's Engineering Standard.

One natural circulation steam generator unit designed for outdoor service to deliver 500,000 pounds of steam per hour continuously at normal rated load at a pressure of 1450 psig and a temperature of 1000°F at the superheater outlet. The unit will be fired with pulverized coal, pyrite blend containing 26% FeS_2, designed for pressurized furnace operation and will include the equipment as tabulated below and described hereinafter.

Description of conceptual design is presented in a proposal form for comparison purposes. This should not be interpreted as a bonifide proposal or bid price. The proposal is subject to reevaluation at the time a tender is submitted based on the fuel specifications provided.

SUMMARY PERFORMANCE SHEET – PART ONE

Purchaser : Chemico
Location Unlocated
Design pressure 1575 psig
Date July 1970
Dwg. No. RD-700-51

Fuel Coal and Pyrites Load	100%					
Steam M lb/hr.	500					
Pressure superheater outlet psig	1450					
Temperature steam superheater outlet F	1000					
Pressure boiler drum psig						
Reheat steam M lb/hr.	None					
Temperature steam entering reheater F	-					
Temperature steam leaving reheater F	-					
Pressure steam entering reheater psig	-					
Pressure steam leaving reheater psig	-					
Temp feed entering unit F	430					
Temp feed leaving econ. F						
Temp air entering unit F	80					
Temp air leaving air heater F	532					
Temp gas leaving furnace F	1835					
Temp gas leaving boiler F	1470					
Temp gas leaving economizer F	900					
Temp gas leaving air heater F	502					
Ditto corrected for leakage F	-					
Excess air leaving %	25					
Wet gas entering air heater M lb/hr.	675					
Wet gas leaving air heater M lb/hr.						
Air entering air heater M lb/hr.						
Air leaving air heater M lb/hr.	625					
Draft in furnace in. H_2O	8.86					
Gas side loss thru boiler in. H_2O	+					
Gas side loss thru suphtr. XXXXX in. H_2O	.65					
Gas side loss thru economizer in. H_2O	.12					
Gas side loss thru airheater in. H_2O	4.55					
Gas side loss thru flues in. H_2O	.64					
Gas side loss thru dust collector in. H_2O	2.90					
Air side loss thru air heater in. H_2O	3.45					
Air side loss thru ducts in. H_2O	1.71					
Air side loss thru burners in. H_2O	4.0					
Air side loss, in. H_2O	-					
Air side loss, in. H_2O	-					
Air & gas loss total in. H_2O	18.02					
Pressure loss to psi	-					
Fuel burned M lb/hr or cfm	59.5					
Liberation Btu/hr/cu ft total vol.	17600					
Furn. Cooling Factor net Btu/hr/sq. ft.						
Unit efficiency %	83.2					

SUMMARY PERFORMANCE SHEET – PART TWO

Purchaser Chemico

Location Unlocated

Date

Fuel Coal and Pyrites						
Steam M lb/hr.	500					
Heat Losses.						
Dry gas %	10.2					
Hydrogen and moisture in fuel %	4.2					
Moisture in air %	.23					
Unburned combustible %	.31					
Radiation %	.38					
Unaccounted for and mfrs. margin %	1.5					
Total losses %	16.82					
Efficiency %	83.2					

Performance based on fuel specified below:

Kind	Coal and Pyrites 26% FeS_2 Blend		
Grindability (Hardgrove)	92		
Maximum moisture %	6		
Surface Moisture %	–		
Size	1/4 x 0		
Gas press. at burner	–		
PROXIMATE ANALYSIS	As Received	Moisture Free	Moisture & Ash Free
Moisture	6	–	–
Volatile matter	21.3	22.7	28.5
Fixed carbon /FeS_2	33.8/20.0	36/21.3	45.1/26.4
Ash	18.9	20	
Softening temperature of ash	2450		
ULTIMATE ANALYSIS	As Received	Moisture Free	Moisture & Ash Free
Per cent by Weight			
Ash	18.9	20	–
S	.8	.8	1.0
H_2	2.9	3.0	3.7
C	43.0	46	57.5
CH_4	–	–	–
C_2H_4	–	–	–
C_2H_6	–	–	–
CO	–	–	–
CO_2	–	–	–
H_2O	6	–	–
N_2	1.6	1.7	2.2
O_2	7.0	7.4	9.2
FeS_2	19.8	21.1	26.4
Btu/lb XXXXXX Ash Free	11,250		
Btu/cu ft at 60 F-30" Hg	–		

HEATING SURFACE

Each unit will include the following nominal heating surfaces:

Convection boiler surface	1630	sq ft
Water walls in furnace	5412	sq ft
Radiant superheater	9900	sq ft
Convection superheater	9060	sq ft
Reheater I.	None	sq ft
Reheater II.	None	sq ft
Economizer	4000	sq ft
Air heater	26000	sq ft
Total furnace volume	37690	cu ft
Total furnace surface	6290	sq ft

Boiler and water wall heating surface consists of all of the heat-transfer apparatus in contact internally with the water or wet steam being heated and externally with gas or refractory being cooled, in which the fluid being heated forms part of the circulating system. This surface is measured on the side receiving heat.

Water wall heating surface in the furnace, including walls, floor, roof, partition walls and platens, consisting of bare or covered tubes, is measured as the sum of the projected areas of the extended metallic surface on the furnace side.

Continuation of water wall tubes beyond the furnace gas outlet is included as boiler heating surface and this surface is measured on that portion of the circumferential and the extended metallic surface receiving heat.

All other boiler surfaces, including screen tubes, are measured on that portion of the circumferential and the extended metallic surface receiving heat. Surface is not included in more than one category.

Superheater and reheater heating surface consists of all of the heat-transfer apparatus in contact internally with steam being heated and externally with gas or refractory being cooled. This surface is measured on the side receiving heat.

Radiant superheater or radiant reheater surface in the furnace, including walls, floor, roof, partition walls and platens, is measured as the sum of the projected areas of the tubes and the extended metallic surface receiving heat.

Continuation of superheater tubes beyond the furnace gas outlet is included as convection superheater surface and this surface is measured on that portion of the circumferential and the extended metallic surface receiving heat.

All other superheater and reheater surface, including screen tubes, is measured on the basis of the circumferential and the extended metallic surface receiving heat.

Furnace cooling factor is the heat available per sq ft of heat absorbing surface in the furnace.

Furnace surface is the projected area of tubes and extended metallic surfaces on the furnace side including walls, floor, roof, partition walls, and platens and the area of the plane of the furnace exit which is defined as the entrance to the convection tube bank.

DESIGN AND CONSTRUCTION
NATURAL CIRCULATION STEAM GENERATORS

All the pressure parts for the steam generator will be fabricated from materials with analyses and thicknesses that shall meet with all the requirements of the ASME Boiler Code.

All welded drum and headers seams will be X-rayed and stress relieved in accordance with the ASME code.

The material surfaces of all drums and headers will be cleaned in the shops by shot blasting.

All nozzles will be forged steel and welded to their drums or headers.

The Steam Generator will be furnished with the following drums:

One (1) 66" I.D. Steam Drum 22'-0" between welds. Material SA-212 B

5

DRUM INTERNALS

Efficient drum internals have two essential functions. One is the separation of steam from water in order that the downcomer system will be provided with the de-steamed water necessary for proper and safe circulation. The other is the separation of moisture from steam to provide high steam purity. The drum internals are devised to effectively provide both functions by means of two stages of separation, the first of which operates to provide steam free water to the boiler circulating system, while the second extracts the last traces of water and impurities from the steam delivered. The internals, illustrated on the preceding page, consist of horizontal centrifugal separators located along the side of the drum and unit chevron drier assemblies arranged along the top of the drum.

The total circulating mixture of steam and water from the boiler tubes is directed by means of girth baffles into the horizontal centrifugal separators. The curved path therein causes separation of steam and water, the steam leaving the separator at both sides through orifices, and the water leaving at the bottom through specially constructed drains.

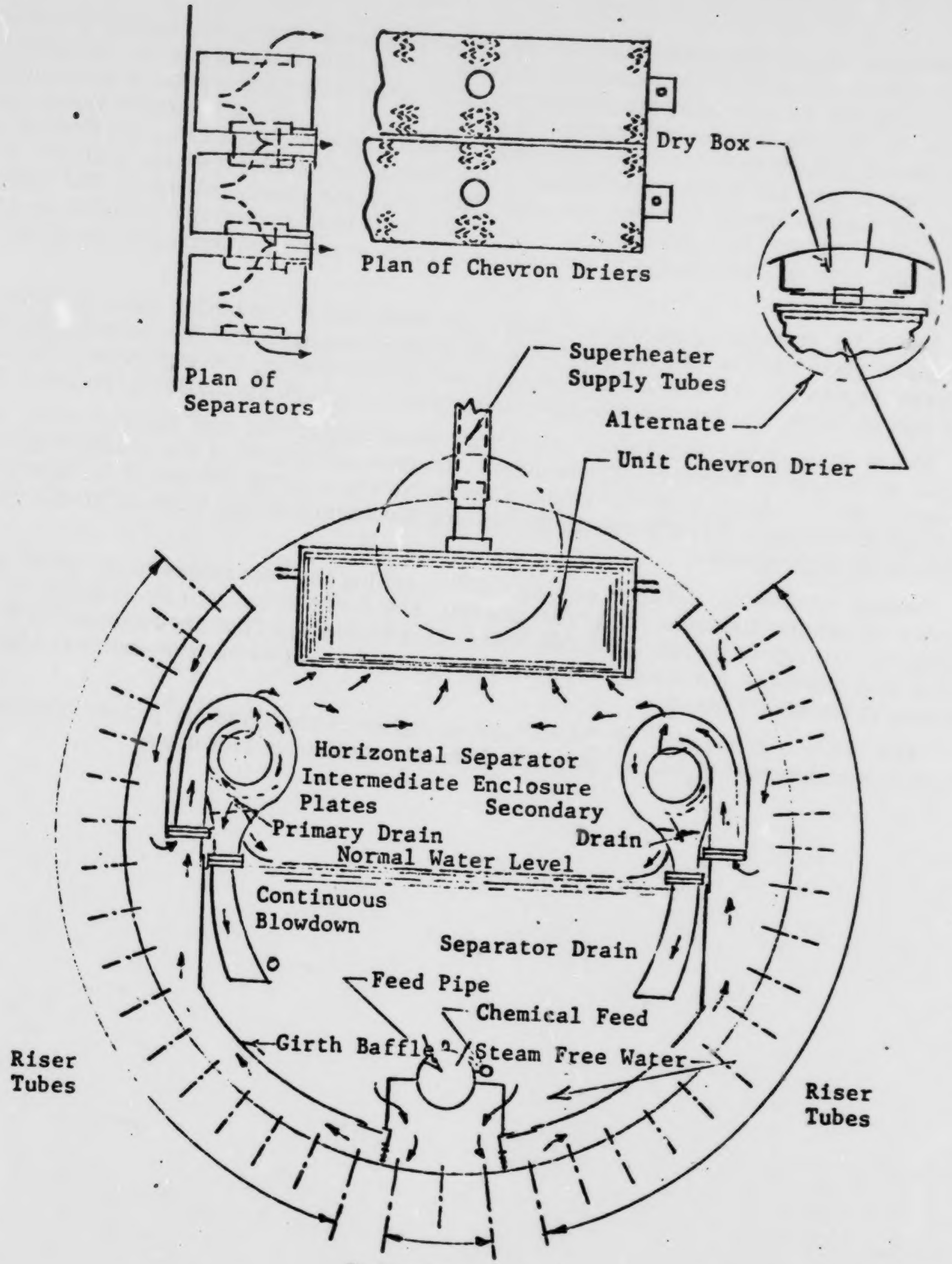
Steam leaving the separators must then pass through the unit chevron drier assemblies at the top of the drum. These driers combine the effects of low steam velocity, and several abrupt changes of the steam flow path, with a large amount of surface to which entrained moisture will adhere. Steam leaving the drum through these internals will have extremely high dryness.

Bolted mechanical flanges are used for attaching the separators to the girth baffle in order to assure tightness. Tapered nozzles are force fitted into the completely welded collection trough to insure tightness of the drier assembly. This arrangement of the drum internals provides the maximum accessability and at the same time delivers high purity steam at the steam outlet.

The steam drum will be fitted with an internal feed pipe for proper distribution of feed water, internal pipes for chemical feed and continuous blowdown.

DRUM INTERNALS

TWO ROWS OF SEPARATORS


Plan of Separators
Plan of Chevron Driers
Dry Box
Superheater Supply Tubes
Alternate
Unit Chevron Drier
Horizontal Separator
Intermediate Enclosure
Plates
Secondary
Primary Drain
Drain
Normal Water Level
Continuous
Blowdown
Separator Drain
Feed Pipe
Chemical Feed
Girth Baffle
Steam Free Water
Riser Tubes
Riser Tubes
Downcomers

FURNACE

The furnace shall be of Monowall Construction and shall consist of welded fin-tube panels.

Tubes will be secured to headers by welding and to drums by welding Tubes will be seamless or resistance welded material. Thickness of tubes, headers, risers and downcomers will be in accordance with ASME Boiler Code rating for the material used.

All material required by the design will be furnished by the Corporation, including welded wall panels, supports, risers, downcomers, closure bars and all material required for providing a sound structure and proper circulation.

DESIGN DATA

Circuit or Wall	Tube OD X ID	Tube Spacing	Material	Number
Front	3"x2.50"	3-3/4" Finned	Carbon Steel	71
Rear	3"x2.50"	3-3/4" Finned	Carbon Steel	71
Side (each)	3"x2.50"	3-3/4" Finned	Carbon Steel	83

HEADERS

Lower Waterwall:

1) Front and Rear - 2 [10-3/4" O.D. x 9.064" I.D.] Each 22' long, weld seam to weld seam. Material SA-210.

2) Side Wall - 4 [10-3/4" O.D. x 9.064" I.D.] Each 10-1/2' long weld seam to weld seam. Material SA-210.

3) Convection Section Rear Wall - 1 [10-3/4" O.D. x 9.064" I.D.] Each 22' long weld seam to weld seam.

Rear Waterwall; Convection Section:

55 - 4" O.D. x 3.5" I.D. tubes on 4-3/4" centerlines

Upper Waterwall

Side wall headers 2 [10-3/4" O.D. x 9.064" I.D.] Each long, weld seam to weld seam. Material SA-210.

Supply tubes: 50 - 3" O.D. x 2.50" I.D. tubes SA-210

SUPERHEATER SPECIFICATIONS

CONSTRUCTION

Superheater elements, headers, connections and spacers will be of suitable material and thickness for the pressure and temperature encountered and in accordance with the ASME Boiler Code. Joints between the elements and the headers shall be secured by welding.

EQUIPMENT INCLUDED

All superheater elements and headers, complete with required steam connections to drum, element spacers, immediately adjacent supports or hangers, and thermometer or thermocouple well at superheater outlet.

Superheater outlet connection outside of setting.
Safety Valves, drain and vent connections as required by the design.

Superheater heating surface is stated on Heating Surface Sheet herein.

DESIGN DATA

Superheater Section	Pendent	Pendent	Pendent	Horizontal
Location in Unit	Furnace	HRA	HRA	HRA
Design Pressure	1625	1625	1625	1625
No. of Sections Wide	---	---	---	---
No. of Loops	1	1	3	-
No. of Tube Elements per loop	8	4	2	2
No. of Rows Deep	11	22	44	44
Tubes: Number	44	44	44	44
Diameter	2.50"x1.75"	2.25"x1.90"	2.25"x1.90"	2.25"x1.96"
Material	SA-213-T22	SA-213-T22	SA-213-T11	SA-213-T11
Tube Spacing:				
Transverse:	24"	12"	6"	6"
Front to Back:	3-3/4"	5"	5"	5"
Inlet Headers				
Number:	1	--	1	1
Diameter	12.75x11.064	--	12.75x11.658	3"x2.50"
Material	Cross over Roof enclosure	--	Cross over Header	SA-212 Drum HRA
Inlet Transfer Pipe:				
Number	1	1	--	1
Diameter	12.75"x	12.75"x11.064	--	12.75"x11.658"
Material	SA-376-TP304H	SA-212-B	--	SA-212-B
Location				
Outlet Headers:				
Number				
Diameter	--	--	--	--
Material				
Outlet Connections:				
Number				
Diameter				
Material				
Location				

ECONOMIZER

CONSTRUCTION

The economizer elements will be supported by tube sheets, or by attachment to pressure parts of the steam generator, as required by the design of the unit.

Tube support sheets and side casing, if required by the design, will be fabricated of steel of composition suitable for the temperatures encountered.

The Corporation's extended surface, if furnished, will consist of 2" OD electric resistance-welded or seamless steel tubing on the outside of which is shrunk, or cast, a series of cast iron gilled rings. These rings form a continuous external cast iron covering for the protection of the steel tubes against the corrosive action of the hot gases.

Joints between elements and headers will be secured by welding.

EQUIPMENT INCLUDED

All pressure parts of the economizer from water inlet to water outlet, and the water connection between economizer and drum, complete with tube supports, casing and immediately adjacent support for attaching to structural steel, as required by the design. Also included are:

Feed water inlet connection outside of setting.
Drain and vent nozzles or connections as required by the design.

DESIGN AND ARRANGEMENT

Total external heating surface is stated on Summary Performance Sheet herein.

The economizer elements will be of the bare tube type and arranged as follows:

Location - heat recovery area downstream convection superheater

Number of rows high — 12

Tube diameter - 2" O.D. x 1.786" I.D. Material SA-210
Tube spacing - 4" vertical center line

Number of rows wide — 44

Tube spacing - 6" transverse center line

Length of elements — 14'-6"

Inlet Header (1) - 8-5/8" O.D. x 7-5/8" I.D. SA-212-B
Outlet Header (1) - 8-5/8" O.D. x 7-5/8" I.D. SA-212-B
Transfer Pipe - (Outlet header - drum) (1) 8-5/8" O.D. x 7-5/8" I.D. SA-212-B

STEAM GENERATOR ACCESSORIES

The accessories for each steam generator will be suitable for the design pressure and will be selected by the Corporation from the products of the manufacturers listed elsewhere in this proposal under "List of Approved Manufacturers."
Accessories to be furnished will be as listed below:

WATER COLUMN AND GAGE Two (2) Diamong, MP-3000 15" vision multi-port bi-color gage glasses complete with support tube assemblies, illuminators and one floor stand with required number of mirrors.

SAFETY VALVES AND NOZZLES

No.	Size (Inches)		
2	2-1/2	Safety valves	Drum
-	-	Safety valves	
1	2-1/2	Safety valves, superheater	
-	-		
-	-	Safety valves, reheater	
-	-	Safety valves, reheater	
-	-		

OTHER ACCESSORIES AND NOZZLES

No.	Size (Inches)		
1	6	Feed valve	(Separated stop-check)
		Check valve	
1	1-1/2	Continuous blow-off valve	
2	1	Vent valve	Drum
1	1	Chemical feed valve	(stainless)
1	12"	Steam gage	
1	1-1/2	Test gage valve	
4	3/4	Water column drain valve	
1	1/2	Gage glass drain valve	
4	1-1/2	Gage glass shut-off valve	
2	1-1/2	Economizer drain (set tandem)	
2	1-1/2	Superheater outlet pralm valves	
4	1	Superheater inter header drains	
2	3/4	Superheater outlet vent valves	

The Corporation will also furnish nozzles for all required auxiliary connections.

The Corporation will furnish the headers and connections of each steam generator with the number of thermowells it considers adequate for the installation. These will be made according to the Corporation's design and fabrication standards. Additional wells or changes of well design will be furnished upon request and at the Purchaser's expense.

REGENERATIVE AIR HEATER

EQUIPMENT INCLUDED

Regenerative type air heater as manufactured by the Air Preheater Corporation , will be as follows:

Total heating surface of air heater for one steam generator is stated on Summary Performance Sheet herein.

Number of air heaters for one steam generator one (1)

Each air heater will be size 21-1/2 hr-30 and equipped with the following:

All driving mechanism including speed reducer and electric motor.

12" cold end layer of heating elements made of corrosion-resistant, low-alloy steel mounted in baskets for side removal.

Hot end layer of heating elements mounted in baskets.

Cleaning device including electric motor and steam piping, valves and fittings to the device.

Insulation anchorages.

Four (4) 20" x 20" access doors.

EQUIPMENT NOT INCLUDED

Electrical connections and starters for driving motors.

Piping and valves for water lines to and from bearing cooling water connections.

FLUES AND DUCTS

Flues and ducts will be of welded steel plate construction. Small sections which can be conveniently shop assembled will be so fabricated. Large sections will be sized for field assembly. All parts will be properly supported, stiffened and made commercially tight. Expansion joints and access doors will be provided where necessary. The ends of flues or ducts will be flanged and drilled for bolting to connecting equipment, or arranged for welding.

The Corporation will furnish only the flues and ducts listed in the following tabulation. Underground flues and ducts will be furnished by the Purchaser as part of the foundations. Hanger and bracket supports, if required for attachment to structural steel, are included.

FLUES	METAL THICKNESS
Economizer to air heater	3/16"
Air heater to dust collector	3/16"

DUCTS	
F.D. Fans to air heater	3/16"
Air heater to windbox	3/16"
Windbox	1/4"

SOOT BLOWERS	
Under the economizer (integral with flue)	1/4"

INSULATION AND OUTER FINISH

The enclosure for the furnace and convection pass will consist essentially of continuously welded fins between adjacent tubes of all peripheral walls, backed by insulation.

The roof of the furnace and the convection pass will be formed by tubular surface, with the integral fins continuously welded to adjacent tubes.

Where transition will occur between the integral fin type tube walls and plate type seals, the transition will be made by scalloped bars.

All castable refractories and special shapes, as required by the design, will be furnished.

The outer surface of the unit will be furnished as described.

Doors for access and inspection will be furnished as required by the design.

Insulation and outer finish materials, for each unit, will be in accordance with the tabulation below:

AREA OR LOCATION	THICKNESS IN INCHES			
	*Insulating Block	Mineral Wool Blanket	Insulating Cement	OTHER MATERIALS

*Insulating block will be , or equal.

PULVERIZER SELECTION AND PERFORMANCE

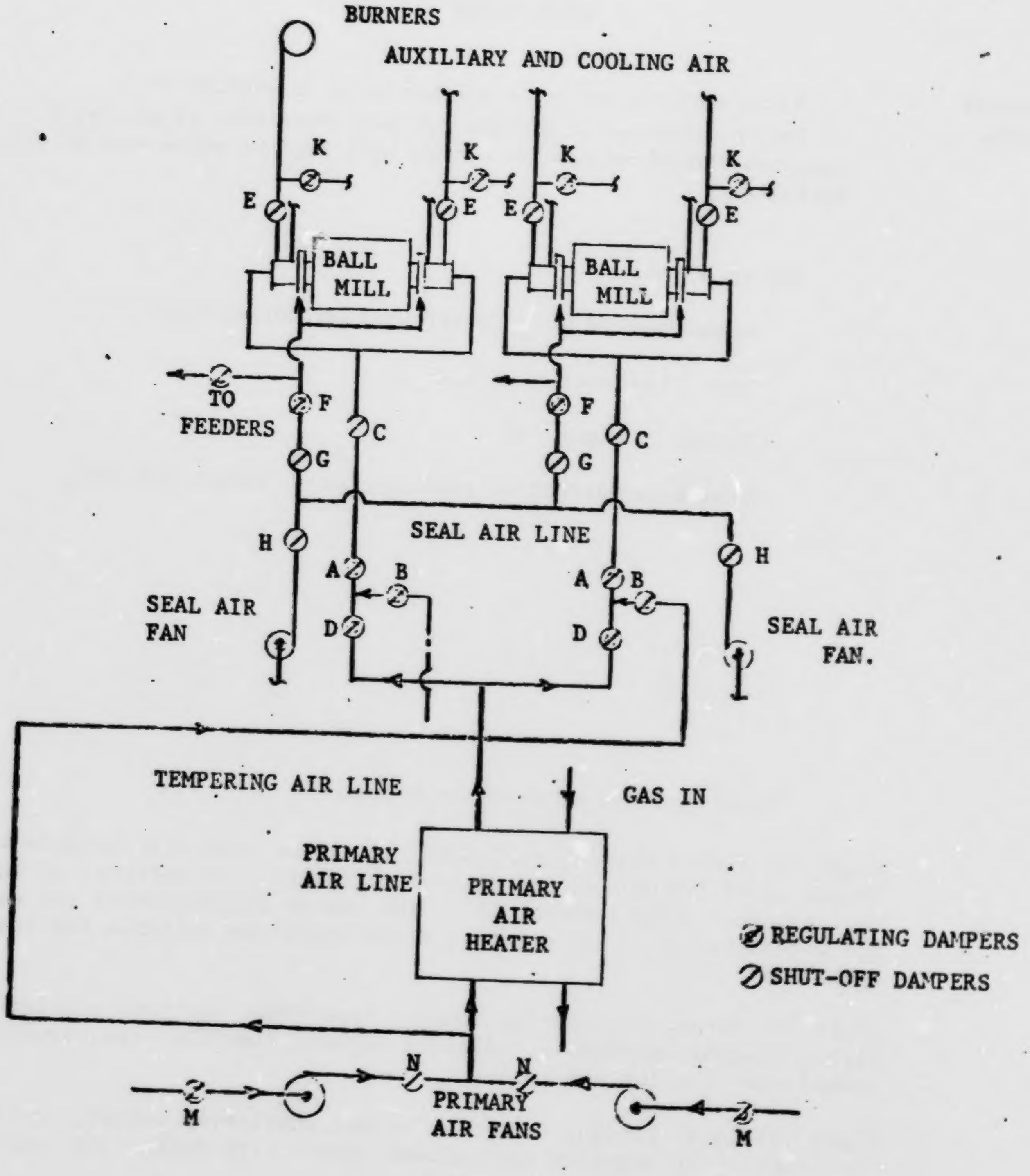
Selection of Pulverizer equipment and the performance stated below are based on the condition that the general arrangement of equipment furnished by the Corporation shall be not less favorable than indicated on drawing . The equipment shall have been erected in accordance with the Corporation's plans and specifications, is in operating condition satisfactory to the Corporation and is properly maintained and operated by the Purchaser. Fuel characteristics shall not be less favorable than indicated by the analyses listed. The Corporation will limit its guarantees to those items of performance specifically listed below under "Guarantee".

MILL SELECTION – Number, Type and Size: Two (2) D5-B, Ball-Tube

Item	Mill Performance			Basis of Mill Selection	
Fuel Specification: (As Fired)					
Type	Coal, Pyrite Blend, 26% FeS_2			Same	
HHV BTU/lb	11,250			11,250	
(1) Grindability (HGU)	90			90	
Total Moisture %	6			6	
Surface Moisture %	-			-	
Feed size	3/8" x 0			3/8" x 0	
(2) Steam Flow – M lbs/hr			500,000	500,000	
Total Fuel Burned lbs/hr			59,500	59,500	
Number of mills in operation:			2	2	
Fuel per Mill – lbs/hr			29,750	29,750	
Fineness: % through #200 USS mesh: % through #50 USS mesh:			90 99	90 99	
Total HP for all Mills, Fans and Feeders in operation:			500	500	
Total HP per Mill, with Fans and Feeder:			250	250	
Corresponding KW per Mill: Based on 90% Motor Efficiency:			210	210	
KW per ton of fuel fired:					

(1) Coal blend thermally pre-dried at coal cleaning plant allowance made for 6 % moisture.

(2) Design for full load operation only.


BURNERS
AUXILIARY AND COOLING AIR
K
K
K
K
E
E
E
E
BALL MILL
BALL MILL
TO FEEDERS
F
F
C
C
G
G
SEAL AIR LINE
H
H
A
B
A
B
SEAL AIR FAN
SEAL AIR FAN.
D
D
TEMPERING AIR LINE
GAS IN
PRIMARY AIR LINE
PRIMARY AIR HEATER
REGULATING DAMPERS
SHUT-OFF DAMPERS
N
N
M
M
PRIMARY AIR FANS

DISTRIBUTION OF AIR FLOW

BURNERS

EQUIPMENT INCLUDED

Burner equipment and burner windbox will be as described below:

Burner windbox will be of welded steel plate construction. All parts will be properly supported, stiffened and made commercially tight. Provision will be made for support of the burners.

Burners will be:

As manufactured by Foster Wheeler Corporation

Type horizontal intervane

Number eight (8)

Suitable for pulverized coal pyrite blend, 26% FeS_2

Burner equipment will include the following:

Eight (8) Foster Wheeler horizontal intervane type coal burners with forced draft fronts and air control registers. Illustrated on following page. Burner throat 30". The burner air registers are equipped with three position electric motor operators suitable for remote operation.

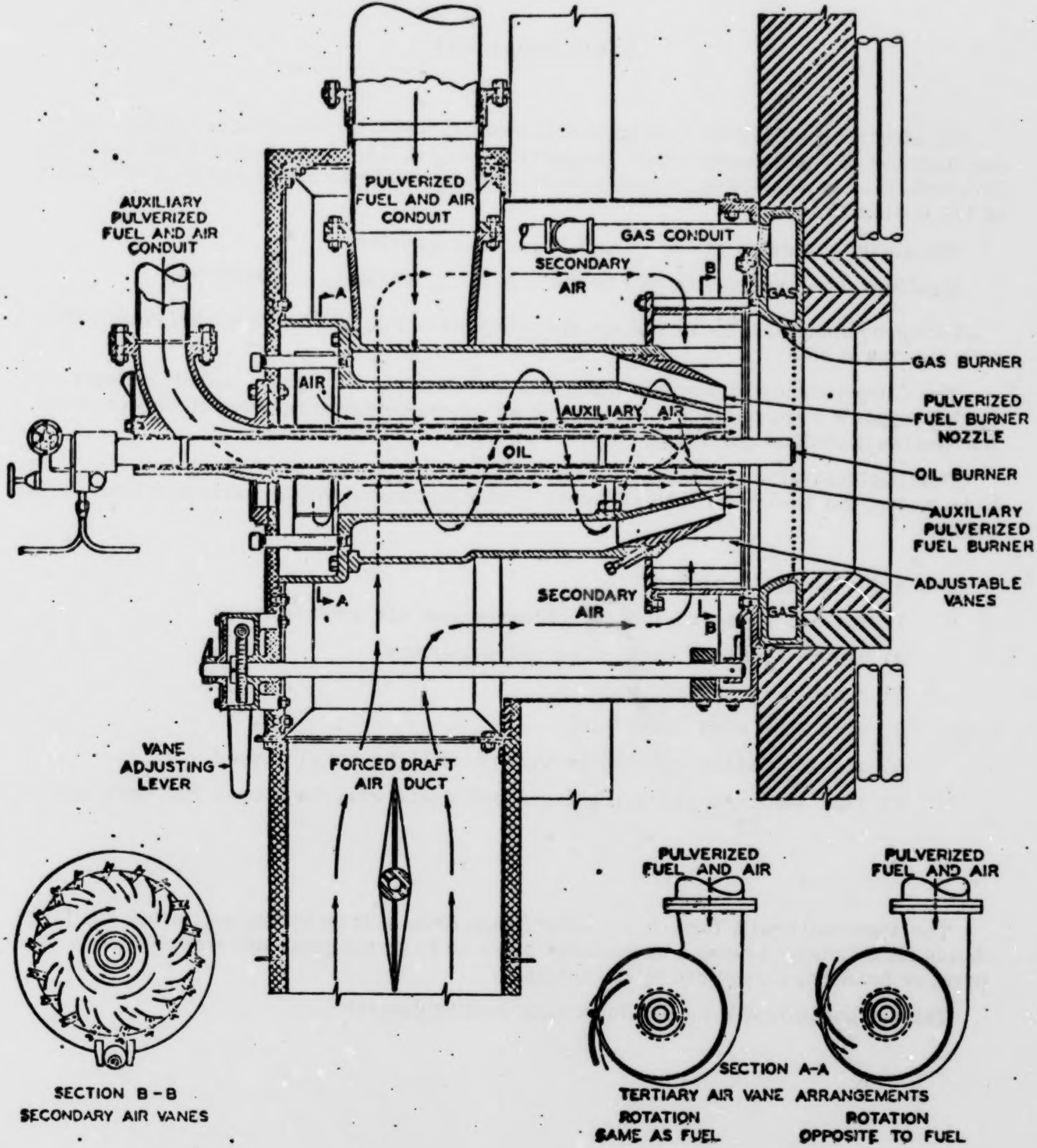
Eight (8) Forney Engineering Company type QPMAL ignitors complete with retractor assemblies, solenoid valves, flexible hose, ignitor transformer housing and cable.

Eight (8) Local Ignitor Control Station, start-stop switch, ignitor "on" light, air register open-closed switch with indicating lights.

Two (2) Burner front relay cabinets with motor reversing contractors and auxiliary relat circuit breakers wired to terminals.

One (1) Remote ignitor control panel insert, complete with eight ignitor control "on-pff" switches and "on lights and 24 register "open-closed" switches and indicating lights.

Note: No flame proving for ignitor or main flame, fuel pumping or transportation equipment is included.


PULVERIZED FUEL AND AIR CONDUIT
AUXILIARY PULVERIZED FUEL AND AIR CONDUIT
GAS CONDUIT
SECONDARY AIR
A
B
GAS
GAS BURNER
AIR
AUXILIARY AIR
PULVERIZED FUEL BURNER NOZZLE
OIL
OIL BURNER
AUXILIARY PULVERIZED FUEL BURNER
ADJUSTABLE VANES
SECONDARY AIR
A
B
GAS
VANE ADJUSTING LEVER
FORCED DRAFT AIR DUCT
PULVERIZED FUEL AND AIR
PULVERIZED FUEL AND AIR
SECTION B - B
SECONDARY AIR VANES
SECTION A-A
TERTIARY AIR VANE ARRANGEMENTS
ROTATION SAME AS FUEL
ROTATION OPPOSITE TO FUEL

HORIZONTAL INTERVANE BURNER EQUIPPED FOR PULVERIZED COAL, GAS AND OIL FIRING

STRUCTURAL STEEL

All structural steel will be designed in accordance with the latest Rules of the American Institute of Steel Construction. Diagonal bracing will be used where lateral loads are involved. Beams supporting pressure parts shall be designed for a maximum deflection of 1/2 inch in 10 feet.

The steam generator will be top supported.

Structural steel and casing will be suitable for outdoor service.

Firing equipment, if located at the operating elevation, will be supported on Purchaser's structural steel.

The Corporation will furnish horizontal and vertical buckstays, and all hangers and spring supports required by the design, for all other equipment included in this proposal. All steelwork shall be painted one coat before shipment from factory.

The Corporation will furnish complete supporting steel structure, including base plates. No load other than steam generator equipment will be carried unless stated below:

The structure will provide for:

1) lateral support of dust collector and air preheater
2) piping within 5 feet of street structure
3) seismic factor of .048
4) wind load - 30 lb/sq. in.
5) all insulation exposed to weather will be metal lagged
6) flat surfaces of casing flues and ducts will be sloped for drainage.

The Purchaser will furnish all foundations. If the unit is bottom supported, the foundation shall include concrete or masonry piers up to steam generator wall support members, or headers, if required by the design.

The Corporation will furnish foundation loading diagrams.

SOOT BLOWERS

The Corporation will furnish soot blowing equipment as described below.
Soot blowers will be manufactured by:
The soot blowing system will blow with steam at 850 psi and 750° F.
Soot blowers, pipe, valves and fitting will be suitable for 900 psi.

Type of drive and method of operation:

Electric motor operated, automatic sequential type with operating panel for mounting on purchaser's control board. All starters shall be mounted as individual units on blowers.

Soot Blower Descriptive Data:

No.	Type	Length or length of travel	Location
8	Full retract	22'	Furnace; superheater passes Economizer
5	Wall deslagger		Furnace Air heater

Element material will be as required by the service.

Pipe, Valves and Fittings to be furnished by

Items	Air or Steam	Function	Terminal Points

Air supply if required will be furnished by Purchaser.

Piping 2" and under, if furnished by the Corporation, will be supplied in random. lengths and shall be fitted in the field by the erection contractor. Diagram showing location of expansion loops and fixed supports will be provided by the Corporation.

If electrical drives and controls are supplied for soot blowers, all equipment will be shop wired to terminal blocks and all electrical wiring and switches external to the equipment will be furnished by the Purchaser.

Electrical Accessories

Reversing starters
Nonreversing starters

EQUIPMENT, MATERIAL AND SCOPE OF WORK
AUTOMATIC SEQUENTIAL, STEAM BLOWING, ELECTRIC MOTOR DRIVEN, ELECTRICALLY CONTROLLED SOOT BLOWER SYSTEM

3 - Model IK-525 long retractable blowers with approx. coverage of 22'-0". Each long retractable unit includes the following:

- A. Series 600 carbon steel construction
- B. 1-1/2 H.P. 460 volt, 3 phase, 60 hertz electric motor attached to the movable carriage
- C. Totally enclosed and sealed carriage assembly to contain a completely geared drive mechanism
- D. Self-locking geared drive to prevent lance tube from becoming self-propelled when operating power is not applied
- E. Quick disconnect plug in power voltage conductors to blower motor
- F. Mechanically operated poppet type blowing medium valve with adjustable pressure control and stellited valve seat
- G. Positive pressure wallbox.

14 - Model IR3 short retractable wall blowers equipped as follows:

- A. Series 600 carbon steel construction
- B. Fixed position 1/6 H.P. TENV electric motor
- C. Mechanically operated poppet type valve with adjustable pressure control
- D. Flexible valve seat and disc with stellited seat trim and stainless steel disc
- E. Positive pressure wallbox

1 - Set of Air Heater control mechanism and mounting bracket to include the following:

- a. 1-1/2" DIAMOND Series 600# steam admission valve
- b. Components required for remote operation of the air preheater cleaning device
- c. Electric motor to be furnished by others.

1 - DIAMOND SELECTRONIC all silicon, solid state soot blower control panel, insert type with self-contained enclosure for operation of the boiler cleaning system from the control room. The cleaning system control panel will provide for the following:

- A. Master control enclosure to contain a power supply, all control components mounted on plug-in type module boards, selector switches for each of 23 units, alarm devices and enunciator lights for each of the following functions:
  1. Control voltage
  2. Auto or continuous operation of steam valve
  3. IK-motor overload
  4. Low blowing medium pressure
  5. IK-forward travel
  6. IK-reverse travel

7. Sequence finish

B. Ammeter to indicate motor current
C. Elapse timer alarm
D. Graphic boiler diagram
E. Unit indicating lights at each soot blower location.

ELECTRICAL ACCESSORIES

Master reversing starter system with individual non-reversing starters mounted on blower.

1 - Master Reversing Starter, Size 1, NEMA III
8 - Non-reversing starters, Size "0", NEMA III - IR
14 - Non-reversing starters, Size 00, NEMA III - IR
1 - Non-Reversing starters, Size 00, NEMA III - APC
23 - Joy Mfg. Co. heavy duty push buttons, NEMA IV, one (1) each to be mounted and wired per blower.

PIPE, VALVES & FITTINGS

All piping is furnished in random lengths for fabrication in the field. Piping drawings will be furnished to show general routing of soot blower piping and to assist the designer and erector in providing an adequate supply of blowing medium, proper piping drainage, and to show need for supports, guides and hangers. Final routing of piping is the responsibility of others.

Thermal and mechanical stresses on the piping systems will be considered to the extent of providing schematic information, to indicate the need for expansion provisions.

1 - 2" Emergency stop valve
1 - 2" Fisher automatic main line valve Type 667 B-DBQ 1500# WC6 body
1 - 2" Main line
22 - 2" Branch lines
1 - 1-1/4" Trap and strainer
1 - 1-1/2" Main line - APC
1 - 1-1/2" Branch line - APC
2 - 3/4" Traps and strainers - APC
9 - 3/4" By-pass valves
1 - Set drawings
Pipe supports, guides and hangers as required.

STEAM PRESSURE REDUCING STATION

1 - 2" Fisher type 667, DBQ WC6 body, 1500# PSIG reducing valve with 4100UR controller and S. O. valve, type 667 operator with 3560A positioner, Consolidated Fig. 1553 safety valve, handjack, discharge elbow, mounting tee, fittings, etc.

TO BE PROVIDED BY OTHERS

a. Support plates and sleeves to attach blowers to boiler and furnace walls.

b. Structural supports for IK Units.

c. Source of suitable electric current, as stated in quotation.

d. Electric wiring to interconnect blowers, panel, push button stations, motor starters, and source of electric current.

e. Labor, supervision, scaffolding, rigging and other costs incidental to installation of proposed boiler cleaning equipment.

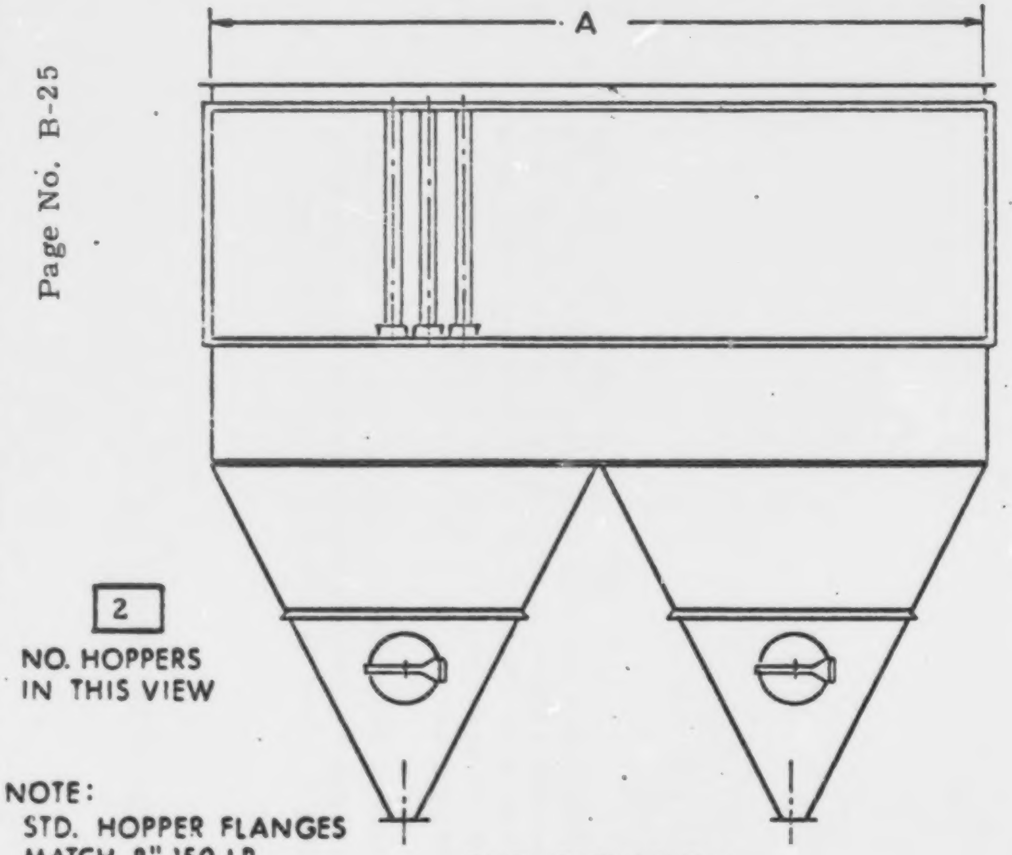
f. Sealing and aspirating air piping from source of supply to individual blower pressure seals.

DUST COLLECTOR

The Corporation will furnish one (1) mechanical dust collector, Type 604 BWNS-15-270, manufactured by UOP Air Correction Division or equivalent, as described on following pages.

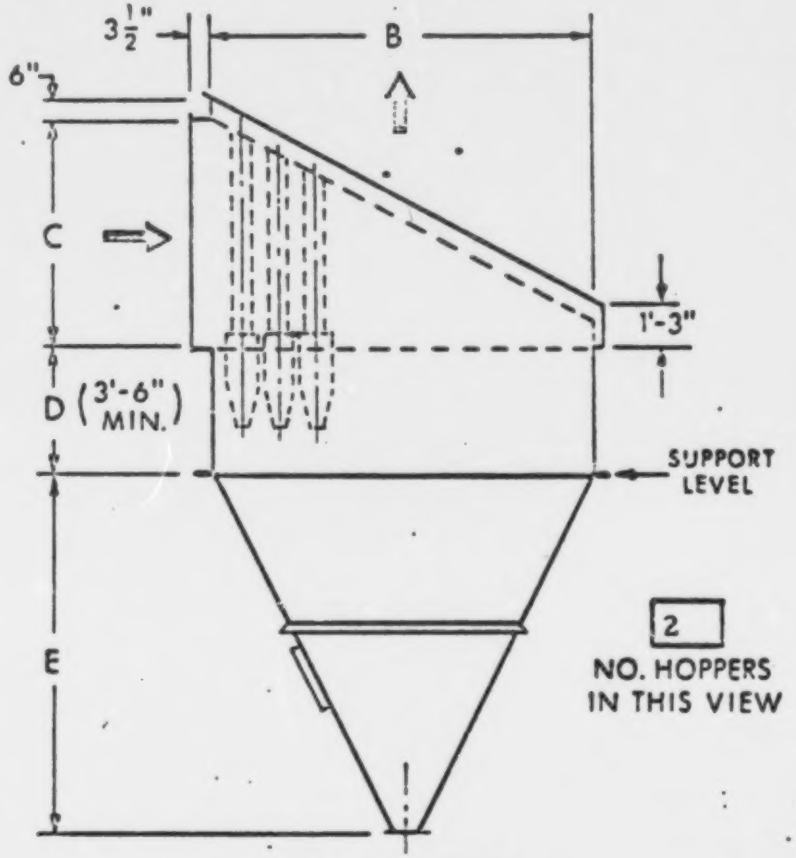
The dust collector will be of the mechanical type designed for an overall efficiency of 83% on the basis of a flyash analysis with not more than 30% less than 10 microns in size. The maximum loss through the collector at 500,000 lb/hr boiler capacity will not exceed 2.9" H_2O. The hopper capacity will be sufficient for hours ash storage with an ash density of [illegible] lb/cu ft.

SIDE INLET – TOP OUTLET


A
2
NO. HOPPERS
IN THIS VIEW

NOTE:
STD. HOPPER FLANGES
MATCH 8" 150 LB.
ASA DRILLING

END ELEVATION


$3\frac{1}{2}$"
B
6"
C
D (3'-6" MIN.)
E
1'-3"
SUPPORT LEVEL
2
NO. HOPPERS
IN THIS VIEW

SIDE ELEVATION

DESIGNATION	DIMENSIONS (FEET & INCHES)					WEIGHT		DUST CAP.
DESIGN	A	B	C	D	E	WITHOUT DUST LOAD	WITH DUST LOAD	CU. FT.
104BWHS-15-270	18-8	15-8	9-3	3-6	8-8	51,000		900

NOT FOR CONSTRUCTION – DIMENSIONS APPROXIMATE ONLY

COLLECTOR SUPPORTS MOUNTED ON CASING, SUPPLIED BY MANUFACTURER
STRUCTURAL STEEL, ON WHICH COLLECTOR SUPPORTS REST, SUPPLIED BY OTHERS

DESIGN 100 SERIES TUBULAR DUST COLLECTOR
DIMENSION SKETCH

BY:	DATE:	FILE: 001-1359	SK. NO. 3

FORM NO. 5-062

TERMINAL POINTS - PART I

The equipment furnished by the Corporation will terminate at the following points beyond which connections and equipment are to be furnished by the Purchaser:

Major Pressure Part Terminal Points:	Number	Size	Type	Arrangement
Superheater Outlet	1	12.75"		Single end
Reheater #1 Inlet	--	--	--	--
" #1 Outlet	--	--	--	--
Reheater #2 Inlet	--	--	--	--
" #2 Outlet	--	--	--	--
Economizer Inlet	1	8-5/8"		Center

1. Superheater Outlet, Reheater Inlet, Reheater Outlet and Economizer Nozzles will terminate immediately outside of the steam generator casing.
2. Safety Valves will terminate at valve discharge flange.
3. Feed stop and check valves will be located in Purchaser's piping.
4. Economizer Hopper will terminate at Outlet Flange.
5. Drain and Sampling Connections will terminate at main operating floor level.
6. Flues and Ducts will terminate at the force draft fan discharge on the air side and at dust collector inlet flange on the gas side.
7. Thermocouples will terminate at common junction boxes adjacent to the boiler casing.
8. Dust Collector Connections will terminate at the flue gas outlet flanges and at the outlet flanges of their hoppers.
9. Sealing Air will be manifolded and piped to F.D. fan.
10. Aspirating Air Piping will terminate in one connection located at the basement level.
11. Electrical Equipment will be furnished without wiring or controls, unless specifically described in this proposal.

TERMINAL POINTS - PART II

The equipment furnished by the Corporation will terminate at the following points beyond which connections and equipment are to be furnished by the Purchaser:

A. For Solid Fuel Fired Units:

1. FURNACE HOPPER will terminate at the hopper seal castings.

2. FLY ASH HOPPERS will terminate at the outlet flange.

3. RAW COAL CONNECTION to Purchaser's equipment will be at the feeder inlet.

STEAM GENERATING UNIT PERFORMANCE AND GENERATING CONDITIONS - PART I

Performance data for the equipment covered are submitted and made a part of this proposal in accordance with the recommendations of the American Boiler Manufacturers Association.

It is recognized that the performance of the equipment covered in this proposal cannot be exactly predicted for every possible operating condition. In consequence, any predicted performance data submitted are intended to show probable operating results which may be closely approximated but which cannot be guaranteed except as expressly stated in the guarantee clause or clauses in this proposal.

Any performance curves submitted are for the Purchaser's convenience and the performance indicated thereon is not offered by the Corporation, nor to be construed by the Purchaser, as a proposal or contract obligation.

The general arrangement of equipment furnished by the Corporation, and the general design and arrangement of related equipment furnished by others, shall be not less favorable than indicated on the proposal drawing identified on the Summary Performance Sheet herein.

The equipment shall have been erected in accordance with the Corporation's plans and specifications, properly maintained and operated by the Purchaser, and shall be in operating condition satisfactory to the Corporation. The heat absorbing surfaces shall be clean inside and out.

There shall be sufficient forced and/or induced draft fan capacity available to provide the necessary air for combustion at a pressure at the burner windbox to overcome all of the resistance through the unit including the breeching and stack. Means shall be provided to control the flow of the supply of air and of the flue gases down to minimum ratings.

Ambient air conditions:

Temperature of boiler room air	F	80
Relative humidity of boiler room air	%	60
Barometric pressure	in. hg.	29.921
Weight of water per lb of air	lb.	0.013

The fuel characteristics shall not be less favorable than that indicated for the fuel or fuels listed on the Summary Performance Sheet herein.

Operating conditions shall be as stated on the Summary Performance Sheet herein.

Measurements of CO_2 or other properties of the combustion gases in furnace or convection passes shall be determined by sampling uniformly across the width of the unit. No performance tests shall be made unless combustion equipment and the combustion process are functioning normally.

STEAM GENERATING UNIT PERFORMANCE AND GUARANTEE CONDITIONS - PART II

The condition of the concentrated boiler water shall be as shown in the following table for the applicable operating pressure:

Pressure at Outlet of Steam Generating Unit — psig	Total Solids ppm	Total Alkalinity ppm	Suspended Solids ppm
0 - 300	3500	700	300
301 - 450	3000	600	250
451 - 600	2500	500	150
601 - 750	2000	400	100
751 - 900	1500	300	60
901 - 1000	1250	250	40
1001 - 1500	1000	200	20
1501 - 2000	750	150	10
2001 - and higher	500	100	5

The treatment of feed water and the conditioning of boiler water are beyond the control of the Corporation. Therefore, the Corporation shall not be held responsible for damage due to the presence of oil, grease, scale or deposits on the internal surfaces of the equipment; or for damage resulting from foaming caused by chemical conditions of the water, or for damage resulting from corrosion or caustic embrittlement. The Corporation shall not be responsible for carryover resulting from the presence of oil, grease or other contaminating material.

WATER AND STEAM SAMPLING CONDITIONS

Samples of water for testing shall be taken from the continuous blowdown, or from a suitably located sampling pipe, through a cooling coil to prevent flashing. Sampling and determination of boiler water conditions shall be under the methods contained in ASTM Special Technical Publication No. 148.

Samples of condensed steam for determination of solids shall be obtained in accordance with the method specified in the latest edition of ASTM-D-1066, Tentative Method for Sampling Steam.

Solids in the steam sample may be determined by either of the two methods described below:

If the electrical conductivity determination of dissolved solids in the condensed steam is used, it shall be made in accordance with ASTM-D-1125-59, Tentative Method on Electrical Conductivity of Water. Remove dissolved gases from the sample as completely as possible by mechanical means without contaminating the sample with any added material which will increase its conductivity. The conductivity shall be corrected to compensate for residual ammonia, carbon dioxide or other gases remaining in the sample and the dissolved solids shall be calculated from this corrected conductivity. For measuring performance by the electrical conductivity method, the average of ten determinations made at regular intervals throughout the test period shall be used.

If the gravimetric determination of total solids in the condensed steam is used, it may be made in accordance with Method A of the latest edition of ASTM-D-1069, Tests for Suspended and Dissolved Solids in Industrial Waters, or a similar method embodying the essential principles of that specification. For measuring performance by the gravimetric method, the results shall be expressed as the average of three determinations made upon a composite sample which shall be taken throughout the entire test period.

INSPECTION, TEST AND WARRANTY CONDITIONS

Each steam generator will be built in accordance with ASME Boiler Code for working pressure specified on Summary Performance Sheet herein. The Corporation will furnish the Purchaser with a certificate from an authorized boiler inspection and insurance company stating that the steam generator is safe for the design working pressure specified above and conforms with the ASME Boiler Code. The Corporation will pay for shop inspection.

Field inspection by the insurance company shall be paid for by the Purchaser unless the erection of the equipment is to be performed by the Corporation.

When erection is completed, but before installation of the setting, the steam generator shall be tested and made tight by the erection contractor at an hydrostatic pressure one and a half times design pressure. The Purchaser shall provide the water required for said test and introduce same into the boilers when they are ready for test and shall also provide drainage from blow-off when test has been completed.

When a tightness test is required for the furnace enclosure and the steam generator gas passages, the openings of the unit shall be blanked and air shall be admitted until the internal pressure reaches 20 in. W.G. The unit shall then be sealed and, if the pressure drop does not exceed 5.0 in. W.G. in ten minutes, the unit shall be considered acceptably tight.

Performance tests, if required, and performance calculations shall be in accordance with the applicable Short Test Form in the latest edition of the ASME Test Code for Stationary Steam Generating Units, and the measure of performance shall be the results of such tests. Performance calculations shall be based on the steam tables in the latest edition of "Thermodynamic Properties of Steam" by Keenan and Keyes.

Performance tests, of the steam generator or any of the equipment furnished by the Corporation, if required, shall be run within sixty days after the Purchaser shall have received notice from the Corporation that the equipment furnished is ready for testing, it being understood that the Corporation may require preliminary tests. Tests shall be conducted only on one representative unit mutually agreed upon by the Purchaser and the Corporation. The Purchaser, at his own expense, shall make all preparations, furnish all operating and testing personnel and incur all expenses connected with such tests, and shall give to the Corporation at least fifteen days' notice of the date or dates on which tests will be made.

The Corporation's representative shall have access to the records at all times, and the test shall be conducted in a manner to satisfy the Corporation that the specified performance conditions are being maintained. A complete copy of test data and results shall be furnished to the Corporation.

The equipment shall be considered as accepted if tests show that the guarantees have been fulfilled, or if the Purchaser shall fail to have said equipment tested within period herein specified. In case of failure to meet performance guarantees, the Corporation reserves the right to change or replace the equipment furnished so that guaranteed performance will be obtained.

The Corporation assumes no responsibility for damage to boilers or other equipment furnished by it, resulting from improper operation or introduction of improper substances to their interiors.

Appendix XI-C

HIGH SULFUR COMBUSTOR STUDY
500 MW STEAM GENERATOR
CONCEPTUAL DESIGN
PLANT - UNLOCATED

FOSTER WHEELER CORPORATION
CONTRACT NO. 0-59-1177
CHEMICO CORPORATION
CONTRACT NO. 0067C

FOSTER WHEELER CORPORATION
110 SOUTH ORANGE AVENUE, LIVINGSTON, N. J.

Form 276-60

PROPOSAL AND SPECIFICATION

To Chemico

Date July 1970

The Corporation proposes the equipment listed below to be used in accordance with the specifications hereinafter set forth.

General arrangement, principal dimensions and design of the steam generator unit will be as shown on the proposal drawing identified on the Summary Performance Sheet herein. The principal features of the equipment are stated in general terms throughout the proposal and the specific details not fully described will conform to the Corporation's Engineering Standard.

One reheat type, natural circulation steam generator unit, designed for outdoor service to deliver 3,500,000 lbs. of steam per hour continuously at normal rated load at a pressure of 2500 psig and temperature of 1000°F at the superheater outlet and a temperature of 1005°F at the reheater outlet. The unit will be fired with pulverized coal, pyrite blend containing 26% FeS_2, designed for pressurized furnace operation and will include the equipment as tabulated below and described hereinafter.

Description of conceptual design is presented in a proposal form for comparison purposes. This should not be interpreted as a bonifide proposal or bid price. The proposal is subject to reevaluation at the time a tender is submitted based on the fuel specifications provided.

SUMMARY PERFORMANCE SHEET — PART ONE

Purchaser Chemico
Location Unlocated
Design pressure 2875
Date July 1970
Dwg. No. RD-700-54

Fuel Coal and Pyrites Load	100%					
Steam M lb/hr	3300					
Pressure superheater outlet psig	2500					
Temperature steam superheater outlet F	1005					
Pressure boiler drum psig	2650					
Reheat steam M lb/hr	3210					
Temperature steam entering reheater F	629					
Temperature steam leaving reheater F	1005					
Pressure steam entering reheater psig	580					
Pressure steam leaving reheater psig	555					
Temp feed entering unit F	480					
Temp feed leaving econ. F	572					
Temp air entering unit F	80					
Temp air leaving air heater F	530					
Temp gas leaving furnace F	2300					
Temp gas entering reheater F	2100					
Temp gas leaving reheater F	900					
Temp gas leaving air heater F	497					
	-					
Excess air leaving %	25					
Wet gas entering air heater M lb/hr	5150					
Wet gas leaving air heater M lb/hr						
Air entering air heater M lb/hr						
Air leaving air heater M lb/hr	4800					
Draft in furnace in. H_2O	9.70					
Gas side loss thru boiler in. H_2O	-					
Gas side loss thru suphtr. & rehtr. in. H_2O	1.81					
Gas side loss thru economizer in. H_2O	-					
Gas side loss thru airheater in. H_2O	4.15					
Gas side loss thru flues in. H_2O	.84					
Gas side loss thru dust collector in. H_2O	2.90					
Air side loss thru air heater in. H_2O	3.15					
Air side loss thru ducts in. H_2O	1.20					
Air side loss thru burners in. H_2O	5.2					
Air side loss, in. H_2O						
Air side loss, in. H_2O						
Air & gas loss total in. H_2O	19.35					
Pressure loss to psi						
Fuel burned M lb/hr or cfm	456					
Liberation Btu/hr/cu ft total vol.						
Furn. Cooling Factor net Btu/hr/sq. ft.						
Unit efficiency %	82.3					

SUMMARY PERFORMANCE SHEET - PART TWO

Purchaser Chemico
Location Unlocated
Date July 1970

Fuel						
Steam M lb/hr.	3500					
Heat Losses						
Dry gas %	10.2					
Hydrogen and moisture in fuel %	4.2					
Moisture in air %	.23					
Unburned combustible %	.31					
Radiation %	.38					
Unaccounted for and mfrs. margin %	1.50					
Total losses %	16.82					
Efficiency %	83.1					

Performance based on fuel specified below:

Kind	Coal & Pyrites 16% FeS_2 Blend		
Grindability (Hardgrove)	92		
Maximum moisture %	6		
Surface Moisture %	-		
Size	1/4 x 0		
Gas press. at burner	-		

PROXIMATE ANALYSIS	As Received	Moisture Free	Moisture & Ash Free
Moisture	6	-	-
Volatile matter	21.3	22.7	28.5
Fixed carbon	33.8/20.0	36/21.3	45.1/26.4
Ash	18.9	20	
Softening temperature of ash	2450		

ULTIMATE ANALYSIS	As Received	Moisture Free	Moisture & Ash Free
Per cent by weight	-	-	-
Ash	18.9	20	-
S	.8	.8	1.0
H_2	2.9	3.0	3.7
C	43.0	46	57.5
CH_4	-	-	-
C_2H_4	-	-	-
C_2H_6	-	-	-
CO	-	-	-
CO_2	-	-	-
H_2O	6	1.7	2.2
N_2	7.0	7.4	9.2
O_2	18.8	21.1	26.4
Btu/lb Ash free	11,250		
Btu/cu ft at 60 F-30" Hg	-		

HEATING SURFACE

Each unit will include the following nominal heating surfaces:

Convection boiler surface	3,770	sq ft
Water walls in furnace	42,700	sq ft
Radiant superheater	36,880	sq ft
Convection superheater	42,800	sq ft
Reheater I.	122,500	sq ft
Reheater II.	-	sq ft
Economizer	49,500	sq ft
Air heater	273,000	sq ft
Total furnace volume	432,000	cu ft
Total furnace surface	63,080	sq ft

Boiler and water wall heating surface consists of all of the heat-transfer apparatus in contact internally with the water or wet steam being heated and externally with gas or refractory being cooled, in which the fluid being heated forms part of the circulating system. This surface is measured on the side receiving heat.

Water wall heating surface in the furnace, including walls, floor, roof, partition walls and platens, consisting of bare or covered tubes, is measured as the sum of the projected areas of the extended metallic surface on the furnace side.

Continuation of water wall tubes beyond the furnace gas outlet is included as boiler heating surface and this surface is measured on that portion of the circumferential and the extended metallic surface receiving heat.

All other boiler surfaces, including screen tubes, are measured on that portion of the circumferential and the extended metallic surface receiving heat. Surface is not included in more than one category.

Superheater and reheater heating surface consists of all of the heat-transfer apparatus in contact internally with steam being heated and externally with gas or refractory being cooled. This surface is measured on the side receiving heat.

Radiant superheater or radiant reheater surface in the furnace, including walls, floor, roof, partition walls and platens, is measured as the sum of the projected areas of the tubes and the extended metallic surface receiving heat.

Continuation of superheater tubes beyond the furnace gas outlet is included as convection superheater surface and this surface is measured on that portion of the circumferential and the extended metallic surface receiving heat.

All other superheater and reheater surface, including screen tubes, is measured on the basis of the circumferential and the extended metallic surface receiving heat.

Furnace cooling factor is the heat available per sq ft of heat absorbing surface in the furnace.

Furnace surface is the projected area of tubes and extended metallic surfaces on the furnace side including walls, floor, roof, partition walls, and platens and the area of the plane of the furnace exit which is defined as the entrance to the convection tube bank.

DESIGN AND CONSTRUCTION
NATURAL CIRCULATION STEAM GENERATORS

All the pressure parts for the steam generator will be fabricated from materials with analyses and thicknesses that shall meet with all the requirements of the ASME Boiler Code.

All welded drum and headers seams will be X-rayed and stress relieved in accordance with the ASME code.

The material surfaces of all drums and headers will be cleaned in the shops by shot blasting.

All nozzles will be forged steel and welded to their drums or headers.

The Steam Generator will be furnished with the following drums:

One (1) 66" I.D. Steam Drum 80'-0" between welds. Material SA-212 B

DRUM INTERNALS

Efficient drum internals have two essential functions. One is the separation of steam from water in order that the downcomer system will be provided with the de-steamed water necessary for proper and safe circulation. The other is the separation of moisture from steam to provide high steam purity. The Foster Wheeler drum internals are devised to effectively provide both functions by means of two stages of separation, the first of which operates to provide steam free water to the boiler circulating system, while the second extracts the last traces of water and impurities from the steam delivered. The internals, illustrated on the preceding page, consist of horizontal centrifugal separators located along the side of the drum and unit chevron drier assemblies arranged along the top of the drum.

The total circulating mixture of steam and water from the boiler tubes is directed by means of girth baffles into the horizontal centrifugal separators. The curved path therein causes separation of steam and water, the steam leaving the separator at both sides through orifices, and the water leaving at the bottom through specially constructed drains.

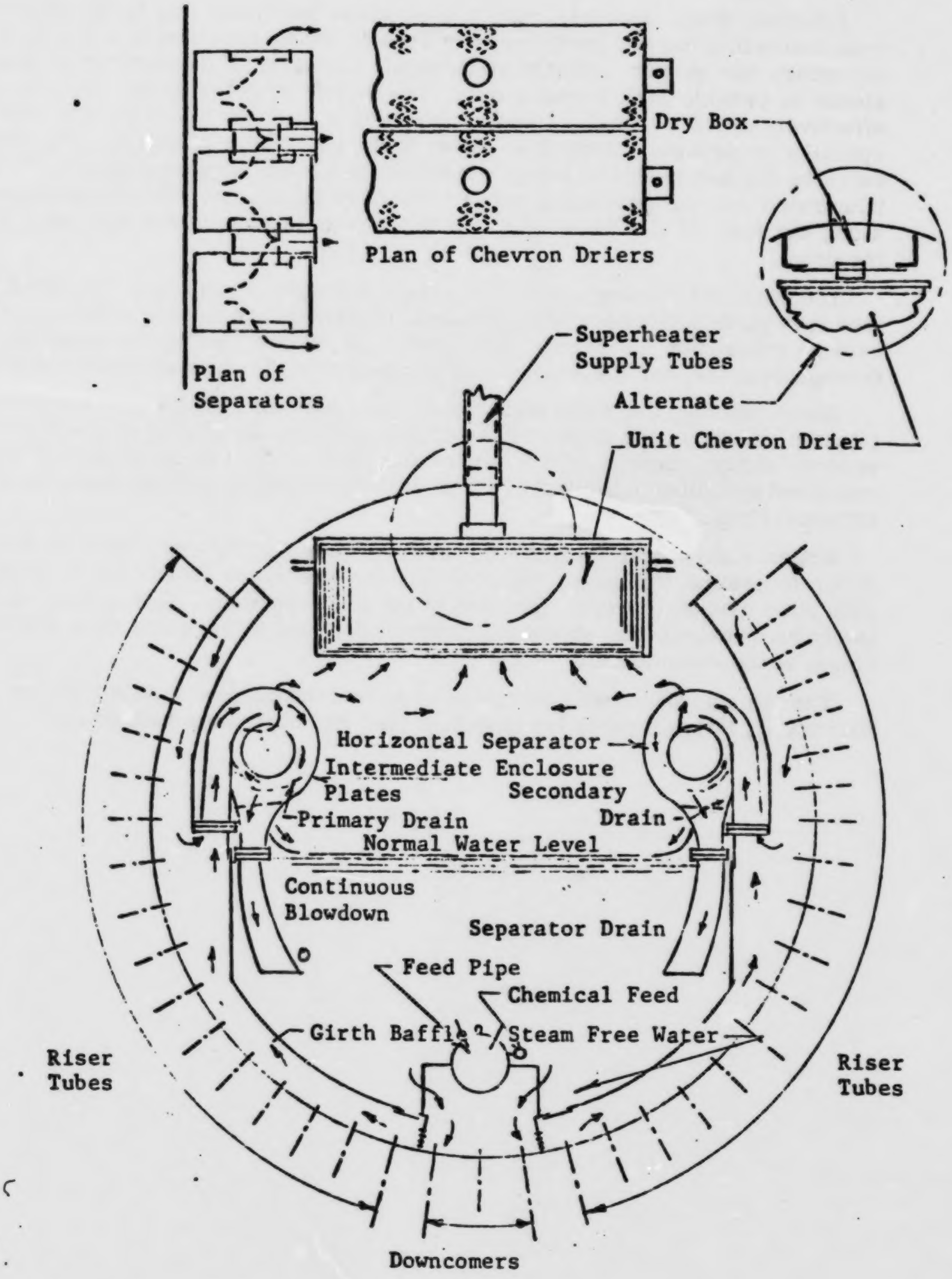
Steam leaving the separators must then pass through the unit chevron drier assemblies at the top of the drum. These driers combine the effects of low steam velocity, and several abrupt changes of the steam flow path, with a large amount of surface to which entrained moisture will adhere. Steam leaving the drum through these internals will have extremely high dryness.

Bolted mechanical flanges are used for attaching the separators to the girth baffle in order to assure tightness. Tapered nozzles are force fitted into the completely welded collection trough to insure tightness of the drier assembly. This arrangement of the drum internals provides the maximum accessability and at the same time delivers high purity steam at the steam outlet.

The steam drum will be fitted with an internal feed pipe for proper distribution of feed water, internal pipes for chemical feed and continuous blowdown.

DRUM INTERNALS

TWO ROWS OF SEPARATORS


Dry Box
Plan of Chevron Driers
Plan of Separators
Superheater Supply Tubes
Alternate
Unit Chevron Drier
Horizontal Separator
Intermediate Enclosure Plates
Secondary Drain
Primary Drain
Normal Water Level
Continuous Blowdown
Separator Drain
Feed Pipe
Chemical Feed
Girth Baffle
Steam Free Water
Riser Tubes
Riser Tubes
Downcomers

FURNACE

The furnace shall be of Foster Wheeler Monowall Construction and shall consist of welded fin-tube panels.

Tubes will be secured to headers by welding and to drums by welding. Tubes will be seamless or resistance welded material. Thickness of tubes, headers, risers and downcomers will be in accordance with ASME Boiler Code rating for the material used.

All material required by the design will be furnished by the Corporation, including welded wall panels, supports, risers, downcomers, closure bars and all material required for providing a sound structure and proper circulation.

DESIGN DATA

Circuit or Wall	Tube O. D.	Tube Spacing	Material	Number
Front	3"x2.40	3-3/4" Finned	Carbon Steel	256
Rear	3"x2.40	3-3/4" Finned	Carbon Steel	256
Side (Each)	3"x2.40	3-3/4" Finned	Carbon Steel	129

SUPERHEATER SPECIFICATIONS

CONSTRUCTION Superheater elements, headers, connections and spacers will be of suitable material and thickness for the pressure and temperature encountered and in accordance with the ASME Boiler Code. Joints between the elements and the headers shall be secured by welding.

EQUIPMENT INCLUDED All superheater elements and headers, complete with required steam connections to drum, element spacers, immediately adjacent supports or hangers, and thermometer or thermocouple well at superheater outlet.

Superheater outlet connection outside of setting.
Safety Valves, drain and vent connections as required by the design.

Superheater heating surface is stated on Heating Surface Sheet herein.

DESIGN DATA

Superheater Section	Pendent	Pendent	Division Wall	Convection
Location in Unit	Furnace	Furnace	Furnace	HRA
Design Pressure	2875	2875	2875	2875
No. of Sections Wide	80	40	7	160
No. of Loops	1	1	-	6-1/2
No. of Tube Elements per loop	5	10	-	2
No. of Rows Deep	10	20	-	26
Tubes: Number	400	400	378	320
Diameter OD x ID	2.50 x 1.75"	2.50 x 1.75"	2.50 x 2.90"	2.50 x 1.15"
Material	SA-213-T22	SA-213-T22	SA-213-T22	SA-210
Tube Spacing:				
Transverse:	6"	12"	-	6"
Front to Back:	2-3/4"	2-3/4"	2-3/4"	5"
Inlet Headers				
Number:		1	1	1
Diameter OD x ID		20" x 15"	22" x 18.38"	14" x 11.750"
Material		SA-335-P-2	SA-106C	SA-106C
Inlet Transfer Pipe:				
Number	44	Same as horizontal superheater outlet connection.	-	
Diameter OD x ID	5" x 4.05			
Material	SA-213-T-22			
Location	From Spray Header			
Outlet Headers:				
Number	1	5	1	
Diameter OD x ID	23.60" x 18.75"	8.625" x 6.90"	22" x 18.38	
Material		SA-335-P-2	SA-106C	
Outlet Connections:				
Number	1	45	2	
Diameter OD x ID	23.60"x 18.75"	5" x 4.00"	22" x 18.38"	
Material	SA-335-P-2	SA-213-T-2	SA-106C	
Location	Center to spray header		Double end	

SUPERHEATER SPECIFICATIONS

CONSTRUCTION

Superheater elements, headers, connections and spacers will be of suitable material and thickness for the pressure and temperature encountered and in accordance with the ASME Boiler Code. Joints between the elements and the headers shall be secured by welding.

EQUIPMENT INCLUDED

All superheater elements and headers, complete with required steam connections to drum, element spacers, immediately adjacent supports or hangers, and thermometer or thermocouple well at superheater outlet.

Superheater outlet connection outside of setting.
Safety Valves, drain and vent connections as required by the design.

Superheater heating surface is stated on Heating Surface Sheet herein.

DESIGN DATA

Superheater Section	Roof	Side Wall	Parting Wall	Rear Wall
Location in Unit	Furnace	HRA	HRA	HRA
Design Pressure	2875	2875	2875	2875
No. of Sections Wide	516	76	256	256
No. of Loops	-	-	-	-
No. of Tube Elements per loop	-	-	-	-
No. of Rows Deep	-	-	-	-
Tubes: Number	516	76	256	256
Diameter OD x ID	1.75 x 1.420	1.75 x .830	1.75 x .830	1.75 x .830
Material	SA-213-T11	SA-178C	SA-178C	SA-178C
Tube Spacing:				
Transverse:	1-7/8"	3-3/4" Finned	3-3/4" Finned	3-3/4" Finned
Front to Back:	-	-	-	-
Inlet Headers				
Number:	1	2	Same as Roof Outlet Header	Same as Roof Outlet Header
Diameter OD x ID	10.75 x 8.75	8.625 x 7.00		
Material	SA-106C	SA-106C		
Inlet Transfer Pipe:				
Number	36	30		
Diameter OD x ID	5" x 4"	5" x 4"	-	-
Material	SA-210	SA-210		
Location	From Drum	From Drum		
Outlet Headers:				
Number	1	2	Collecting Hor	Same as Parting wall
Diameter OD x ID	10.75 x 8.75	8.625 x 7.00	14.00 x 12.50	
Material	SA-106C	SA-106C	SA-106C	
Outlet Connections:				
Number	To HRA Side, Parting and Rear Walls	36		
Diameter OD x ID		4.00 x 3.25	-	-
Material		SA-210		
Location		To Collect Header		

REHEATER SPECIFICATIONS

Reheater elements, headers, connections and spacers will be of suitable material and thickness for the pressure and temperature encountered and in accordance with the ASME Boiler Code.

Joints between the elements and the headers shall be secured by welding.

All reheater elements and headers are included, complete with required elements spacers, immediately adjacent supports or hangers, and thermometer or thermocouple well at reheat outlet. Also included are:

Reheater inlet connection outside of setting.
Reheater outlet connection outside of setting.
Safety valves and drain connections as required by the design.

Reheater heating surface is stated on Heating Surface Sheet herein.

DESIGN DATA

Reheater Section	Horizontal	Horizontal	Vertical Leg	Outlet
Location in Unit	HRA	HRA	HRA	HRA
Design Pressure	725	725	725	725
No. of Sections Wide	160	160	80	80
No. of Loops	2	2	1	1/2
No. of Tube Elements per loop	7	7	14	14
No. of Rows Deep	28	28	28	14
Tubes: Number	1120	1120	1120	1120
Diameter	2.50 x 2.232	2.50 x 2.232	2.50 x 2.232	2.50 x 2.00
Material	SA-178CET2	SA-213 T-2	SA-213 T-22	SA-213 T-22
Tube Spacing:				
Transverse:	6"	6"	12"	12"
Front to Back:	5"	5"	5"	5"
Inlet Headers				
Number:	1	–	–	–
Diameter	30 x 28"			
Material	SA-106C			
Inlet Transfer Pipe:				
Number	1	–	–	–
Diameter	30 x 28"			
Material	SA-106C			
Location	Single End			
Outlet Headers:				
Number	–	–	–	1
Diameter				30 x 34"
Material				SA-335 P-22
Outlet Connections:				
Number	–	–	–	1
Diameter				30 x 34"
Material				SA-335 P-22
Location				Single End

ECONOMIZER

CONSTRUCTION

The economizer elements will be supported by tube sheets, or by attachment to pressure parts of the steam generator, as required by the design of the unit.

Tube support sheets and side casing, if required by the design, will be fabricated of steel of composition suitable for the temperatures encountered.

The Corporation's extended surface, if furnished, will consist of 2" OD electric resistance-welded or seamless steel tubing on the outside of which is shrunk, or cast, a series of cast iron gilled rings. These rings form a continuous external cast iron covering for the protection of the steel tubes against the corrosive action of the hot gases.

Joints between elements and headers will be secured by welding

EQUIPMENT INCLUDED

All pressure parts of the economizer from water inlet to water outlet, and the water connection between economizer and drum, complete with tube supports, casing and immediately adjacent support for attaching to structural steel, as required by the design. Also included are:

Feed water inlet connection outside of setting.
Drain and vent nozzles or connections as required by the design.

DESIGN AND ARRANGEMENT

Total external heating surface is stated on Summary Performance Sheet herein.

The economizer elements will be of the bare hose type and arranged as follows:

Location - heat recovery area downstream on the convection superheater.

Number of rows high — 24

Tube diameter - 2" OD x 1.624 I.D. Material SA-210
Tube spacing - 4" Vertical Centerline

Number of rows wide — 160

Tube spacing - 6" transverse centerline

Length of elements —

*Inlet header - 8-5/8" OD x 7.00 ID SA-212-B
*Outlet header - 8-5/8" OD x 7.00 ID SA-212-B
transfer pipe - (outlet-drum) (1) 8-5/8" OD x 7.00 ID SA-212-B

* Headers located in vestibules as shown in RD-700-54

STEAM GENERATOR ACCESSORIES

The accessories for each steam generator will be suitable for the design pressure and will be selected by the Corporation from the products of the manufacturers listed elsewhere in this proposal under "List of Approved Manufacturers." Accessories to be furnished will be as listed below:

WATER COLUMN AND GAGE One (1) Color-Port Water Level Gauge, 15-1/2", vertical visibility with circulating tie bar, water column complete with color-port, illuminator, and hood for direct viewing. Two (2) panel mounted remote liquid level indicators, pressure-temperature compensated, complete with necessary tubing and fittings for connection to drum.

SAFETY VALVES AND NOZZLES

No.	Size (Inches)		MANUFACTURER	CAT. NO.
6	3	Safety valves drum	Foster	15005MW
		Safety valves		
1	3	Safety valves, superheater outlet	Foster	15005MW
1	2-1/2	Safety valves, superheater outlet	Foster	15005MW
6	6	Safety valves, reheater inlet		
2	6	Safety valves, reheater outlet		

OTHER ACCESSORIES AND NOZZLES

	1	16	Feed valve	Edward	75164
	1	16	Check valve	Edward	75944
	1	1-1/2	Continuous blow-off valve	Edward	3624
	1	1-1/2	Vent valve	Edward	3624
	1	1-1/2	Chemical feed valve	Edward	3624
	1	12	Steam gage	Crosby	–
	1	1-1/2	Test gage valve	Crosby	–
	1	1	Steam gage shut-off valve	Edward	3624
	1	1-1/2	Water column drain valve	Edward	3624
T	1	1/2	Gage glass drain valve	Edward	3624
	2	1-1/2	Gage glass shut-off valve	Edward	3624
T	8	1	Water wall drain valve	Edward	3624
	4	1	Remote level indicator(shut-off valve)	Edward	3624
	8	1-1/2	Superheater drain valve	Edward	3624
	4	1-1/2	Superheater vent valve	Edward	3624
	2	1-1/2	Reheater drain valve	Edward	3624
	2	1-1/2	Reheater vent valves	Edward	3624
	2	1-1/2	Economizer drain valve	Edward	3624
	1	1	Water sampling valve	Edward	3624

The Corporation will also furnish nozzles for all required auxiliary connections.

The Corporation will furnish the headers and connections of each steam generator with the number of thermowells it considers adequate for the installation. These will be made according to the Corporation's design and fabrication standards. Additional wells or changes of well design will be furnished upon request and at the Purchaser's expense.

"T" denotes tandem set

REGENERATIVE AIR HEATER

EQUIPMENT INCLUDED

Regenerative type air heater as manufactured by the air preheater Corporation will be as follows:

Total heating surface of air heater for one steam generator is stated on Summary Performance Sheet herein.

Number of air heaters for one steam generator

Each air heater will be size 32-1/2 - H-30 and equipped with the following:

All driving mechanism including speed reducer and electric motor.

12" cold end layer of heating elements made of corrosion-resistant, low-alloy steel mounted in baskets for side removal.

Hot end layer of heating elements mounted in baskets.

Cleaning device including electric motor and steam piping, valves and fittings to the device.

Insulation anchorages.

Four (4) 20" x 20" access doors.

EQUIPMENT NOT INCLUDED

Electrical connections and starters for driving motors.

Piping and valves for water lines to and from bearing cooling water connections.

FLUES AND DUCTS

Flues and ducts will be of welded steel plate construction. Small sections which can be conveniently shop assembled will be so fabricated. Large sections will be sized for field assembly. All parts will be properly supported, stiffened and made commercially tight. Expansion joints and access doors will be provided where necessary. The ends of flues or ducts will be flanged and drilled for bolting to connecting equipment, or arranged for welding.

The Corporation will furnish only the flues and ducts listed in the following tabulation. Underground flues and ducts will be furnished by the Purchaser as part of the foundations. Hanger and bracket supports, if required for attachment to structural steel, are included.

FLUES	METAL THICKNESS
Economizer to air heater	3/16"
Air heater to dust collector	3/16"
DUCTS	
F.D. fans to air heater	3/16"
Air heater to windbox	3/16"
Windbox	1/4"
SOOT HOPPERS	
Under the economizer and reheater integral part of flues	1/4"

INSULATION AND OUTER FINISH

The enclosure for the furnace and convection pass will consist essentially of continuously welded fins between adjacent tubes of all peripheral walls, backed by insulation.

The roof of the furnace and the convection pass will be formed by tubular surface, with the integral fins continuously welded to adjacent tubes.

Where transition will occur between the integral fin type tube walls and plate type seals, the transition will be made by scalloped bars.

All castable refractories and special shapes, as required by the design, will be furnished.

The outer surface of the unit will be furnished as described.

Doors for access and inspection will be furnished as required by the design.

Insulation and outer finish materials, for each unit, will be in accordance with the tabulation below:

AREA OR LOCATION	THICKNESS IN INCHES			
	*Insulating Block	Mineral Wool Blanket	Insulating Cement	OTHER MATERIALS

*Insulating block will be , or equal.

PULVERIZER SELECTION AND PERFORMANCE

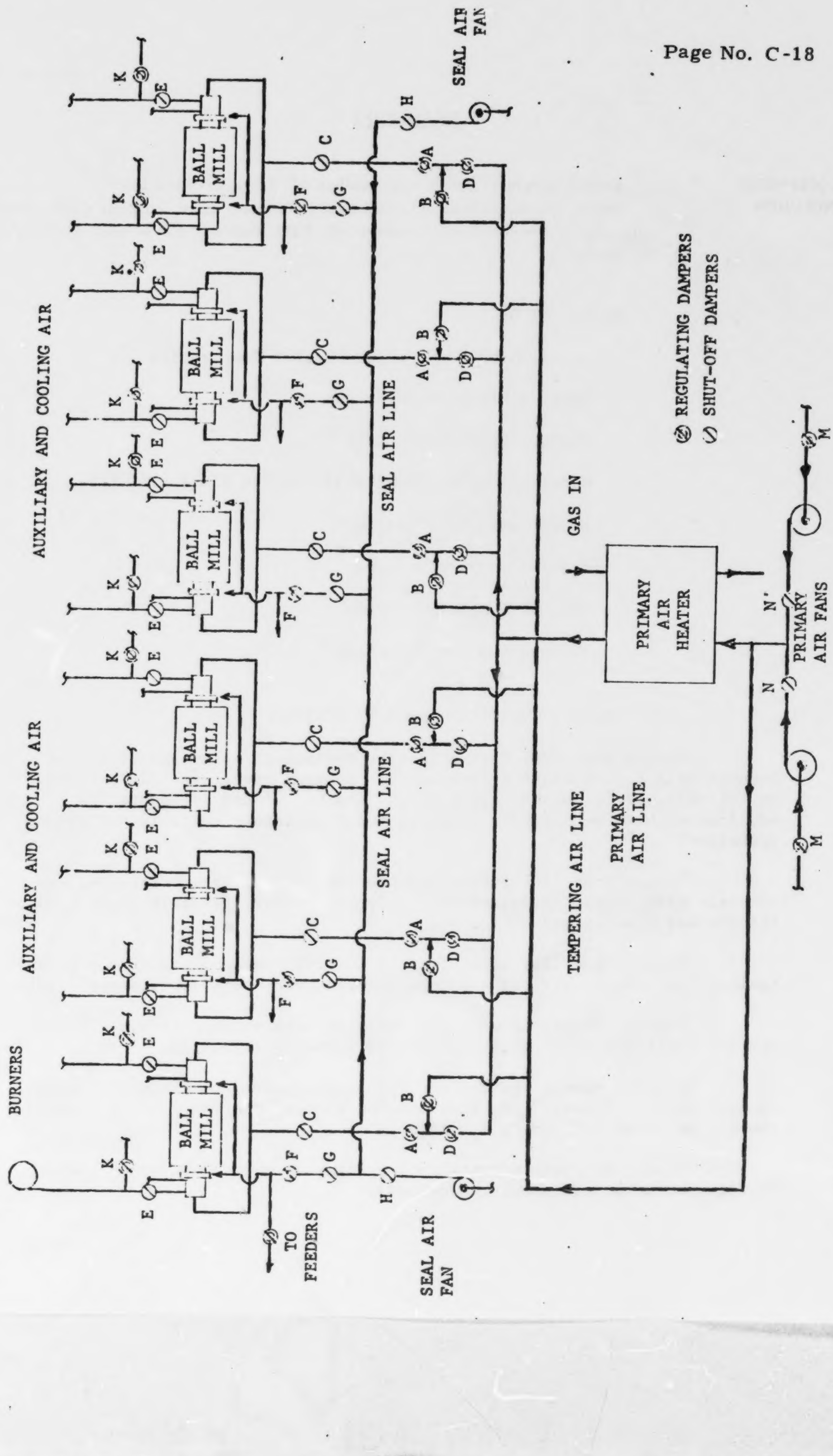
Selection of Pulverizer equipment and the performance stated below are based on the condition that the general arrangement of equipment furnished by the Corporation shall be not less favorable than indicated on drawing . The equipment shall have been erected in accordance with the Corporation's plans and specifications, is in operating condition satisfactory to the Corporation and is properly maintained and operated by the Purchaser. Fuel characteristics shall not be less favorable than indicated by the analyses listed. The Corporation will limit its guarantees to those items of performance specifically listed below under "Guarantee".

MILL SELECTION – Number, Type and Size: Six (6), D8-A, Ball-Tube

Item	Mill Performance			Basis of Mill Selection	
Fuel Specification: (As Fired)					
Type	Coal, Pyrite Blend 26% FeS_2			Same	
HHV BTU/lb	11,250			11,250	
Grindability (HGU)	90			90	
(1) Total Moisture %	6			6	
Surface Moisture %	–			–	
Feed size	3/8" x 0			3/8" x 0	
(2) Steam Flow – M lbs/hr					
Total Fuel Burned lbs/hr			456,000	456,000	
Number of mills in operation:			6	6	
Fuel per Mill – lbs/hr			76,000	76,000	
Fineness:					
% through #200 USS mesh:			90	90	
% through #50 USS mesh:			99	99	
Total HP for all Mills, Fans and Feeders in operation:			3,600	3,600	
Total HP per Mill, with Fans and Feeder:			600	600	
Corresponding KW per Mill: Based on 90% Motor Efficiency:			500	500	
KW per ton of fuel fired:					

(1) Coal blend thermally pre-dried at coal cleaning plant. Allcwance made for 6% moisture.

(2) Design for full load operation only.


BURNERS
AUXILIARY AND COOLING AIR
AUXILIARY AND COOLING AIR
BALL MILL
BALL MILL
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BALL MILL
TO FEEDERS
SEAL AIR FAN
SEAL AIR FAN
SEAL AIR LINE
SEAL AIR LINE
TEMPERING AIR LINE
PRIMARY AIR LINE
GAS IN
PRIMARY AIR HEATER
PRIMARY AIR FANS
REGULATING DAMPERS
SHUT-OFF DAMPERS
A
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BURNERS

EQUIPMENT INCLUDED

Burner equipment and burner windbox will be as described below:

Burner windbox will be of welded steel plate construction. All parts will be properly supported, stiffened and made commercially tight. Provision will be made for support of the burners.

Burners will be:

As manufactured by Foster Wheeler Corporation

Type Horizontal Intervane

Number twenty four (24)

Suitable for pulverizing coal, pyrite blend, 26% FeS_2

Required gas pressure at burner

Required oil pressure at burner

Required oil viscosity at burner

Required steam pressure at burner

Burner equipment will include the following:

Twenty four (24) Foster Wheeler horizontal intervane type coal burners with forced draft fronts and air control registers. (Illustrated on following page, burner throat 50".) The burner and registers are equipped with three position electric motor operators suitable for remote operation.

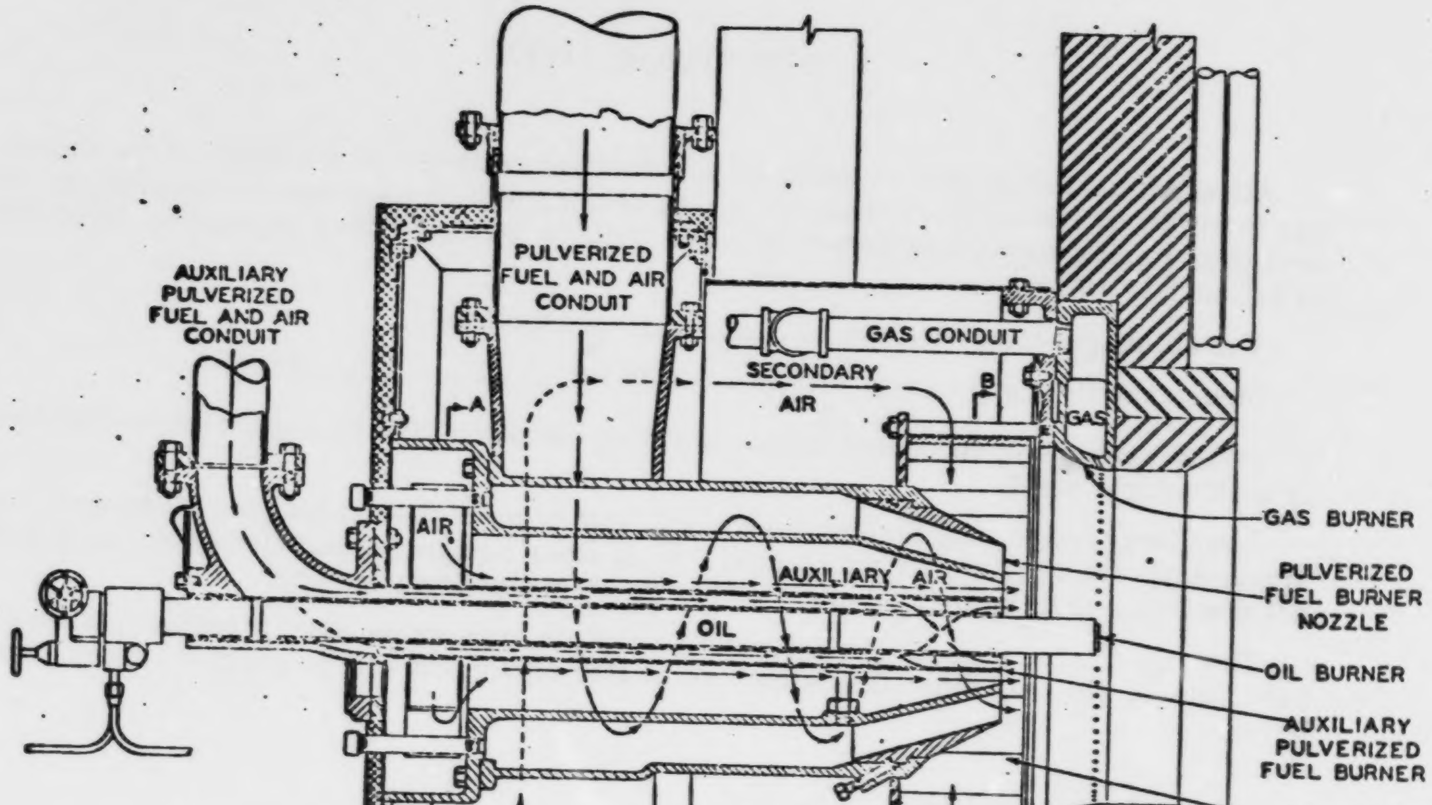
Twenty four (24) Forney Engineering Company Type QPMAL ignitors complete with retractor assemblies, solenoid valves, flexible hose, ignitor transformer housing and cable.

Twenty four (24) Local Ignitor Control Station, start-stop switch, ignitor "on" light, air register open-closed switch with indicating lights.

Two (2) burner front relay cabinets with motor reversing contractors and auxiliary relay circuit breakers wired to terminals.

One (1) remote ignitor control panel insert, complete with eight ignitor control "on-off" switches and "on lights" and 24 register "open-closed" switches and indicating lights.

Note: No flame proving foil ignitor or main flame, fuel pumping on transportation equipment is included.


AUXILIARY PULVERIZED FUEL AND AIR CONDUIT
PULVERIZED FUEL AND AIR CONDUIT
GAS CONDUIT
SECONDARY AIR
B
A
GAS
AIR
AUXILIARY AIR
OIL
GAS BURNER
PULVERIZED FUEL BURNER NOZZLE
OIL BURNER
AUXILIARY PULVERIZED FUEL BURNER
ADJUSTABLE VANES
SECONDARY AIR
A
B
GAS
VANE ADJUSTING LEVER
FORCED DRAFT AIR DUCT
PULVERIZED FUEL AND AIR
PULVERIZED FUEL AND AIR
SECTION B-B
SECONDARY AIR VANES
SECTION A-A
TERTIARY AIR VANE ARRANGEMENTS
ROTATION SAME AS FUEL
ROTATION OPPOSITE TO FUEL

HORIZONTAL INTERVANE BURNER EQUIPPED
FOR PULVERIZED COAL, GAS AND OIL FIRING

STRUCTURAL STEEL

All structural steel will be designed in accordance with the latest Rules of the American Institute of Steel Construction. Diagonal bracing will be used where lateral loads are involved. Beams supporting pressure parts shall be designed for a maximum deflection of 1/2 inch in 10 feet.

The steam generator will be ______________ supported.

Structural steel and casing will be suitable for______________service.

Firing equipment, if located at the operating elevation, will be supported on Purchaser's structural steel.

The Corporation will furnish horizontal and vertical buckstays, and all hangers and spring supports required by the design, for all other equipment included in this proposal. All steelwork shall be painted one coat before shipment from factory.

The__________________will furnish complete supporting steel structure, including base plates. No load other than steam generator equipment will be carried unless stated below:

The Purchaser will furnish all foundations. If the unit is bottom supported, the foundation shall include concrete or masonry piers up to steam generator wall support members, or headers, if required by the design.

The Corporation will furnish foundation loading diagrams.

SOOT BLOWERS

The Corporation will furnish soot blowing equipment as described below.
Soot blowers will be manufactured by: Diamond Power Specialty Corporation
The soot blowing system will blow with steam at 2550 psi and 845° F.
Soot blowers, pipe, valves and fitting will be suitable for 2875 psi.

Type of drive and method of operation:

Electric motor operated, automatic sequential type with operating panel for mounting on purchaser's control board. All starters shall be mounted as individual units on blowers.

Soot Blower Descriptive Data:

No.	Type	Length or length of travel	Location
28	FULL RETRACT	40'	FURNACE, SUPERHEATER AND REHEATER PASSES
40	WALL DESLAGGER		FURNACE
2	AIR HEATER		

Element material will be as required by the service.

Pipe, Valves and Fittings to be furnished by

Items	Air or Steam	Function	Terminal Points

Air supply if required will be furnished by Purchaser.

Piping 2" and under, if furnished by the Corporation, will be supplied in random. lengths and shall be fitted in the field by the erection contractor. Diagram showing location of expansion loops and fixed supports will be provided by the Corporation.

If electrical drives and controls are supplied for soot blowers, all equipment will be shop wired to terminal blocks and all electrical wiring and switches external to the equipment will be furnished by the Purchaser.

CONTROLS:

EQUIPMENT, MATERIAL AND SCOPE OF WORK
AUTOMATIC SEQUENTIAL, STEAM BLOWING, ELECTRIC MOTOR DRIVEN, ELECTRICALLY CONTROLLED SOOT BLOWER SYSTEM

28 - Model IK-525 long retractable blowers with approx. coverage of 40'-0". Each long retractable unit includes the following:

A. Series 600 carbon steel construction
B. 1-1/2 H.P. 460 volt, 3 phase, 60 hertz electric motor attached to the movable carriage
C. Totally enclosed and sealed carriage assembly to contain a completely geared drive mechanism
D. Self-locking geared drive to prevent lance tube from becoming self-propelled when operating power is not applied
E. Quick disconnect plug in power voltage conductors to blower motor
F. Mechanically operated poppet type blowing medium valve with adjustable pressure control and stellited valve seat
G. Positive pressure wallbox

40 - Model IR3 short retractable wall blowers equipped as follows:

A. Series 600 carbon steel construction
B. Fixed position 1/6 H.P. TENV electric motor
C. Mechanically operated poppet type valve with adjustable pressure control
D. Flexible valve seat and disc with stellited seat trim and stainless steel disc
E. Positive pressure wallbox

1 - Set of Air Heater control mechanism and mounting bracket to include the following:

a. 1-1/2" DIAMOND Series 600# steam admission valve
b. Components required for remote operation of the air preheater cleaning device
c. Electric motor to be furnished by others.

1 - DIAMOND SELECTRONIC all silicon, solid state soot blower control panel, insert type with self contained enclosure for operation of the boiler cleaning system from the control room. The cleaning system control panel will provide for the following:

A. Master control enclosure to contain a power supply, all control components mounted on plug-in type module boards, selector switches for each of 69 units, alarm devices and enunciator lights for each of the following functions:

1. Control voltage
2. Auto or continuous operation of steam valve
3. IK-motor overload
4. Low blowing medium pressure
5. IK - forward travel
6. IK - reverse travel
7. Sequence finish

B. Ammeter to indicate motor current
C. Elapse timer alarm
D. Graphic boiler diagram
E. Unit indicating lights at each soot blower location
F. Group control.

ELECTRICAL ACCESSORIES

Master reversing starter system with individual non-reversing starters mounted on blower

1 - Master reversing starter, Size 1, NEMA III
28 - Non-reversing starters, Size 0, NEMA III - IK
40 - Non-reversing starters, size 00, NEMA III - IR
1 - Non-reversing starter, Size 00, NEMA III - APC *
69 - Joy Mfg. Co. heavy duty push buttons, NEMA IV, one (1) each mounted and wired per blower.
***For mounting by others.**

PIPE, VALVES & FITTINGS

All piping is furnished in random lengths for fabrication in the field. Piping drawings will be furnished to show general routing of soot blower piping and to assist the designer and erector in providing an adequate supply of blowing medium, proper piping drainage, and to show need for supports, guides, and hangers. Final routing of piping is the responsibility of others.

Thermal and mechanical stresses on the piping systems will be considered to the extent of providing schematic information, to indicate the need for expansion provisions.

1 - 1/12 Length of Schedule 160 pipe
1 - 1-1/2" Emergency stop valve
2 - 2" Main lines
68 - 2" Branch lines
2 - 1-1/4" Traps and strainers
1 - 1-1/2" Main line - APC
1 - 1-1/2" Branch line - APC
2 - 3/4" Traps and strainers - APC
12 - 3/4" By-pass valves
1 - Set Drawings
Pipe supports, guides and hangers as required.

STEAM PRESSURE REDUCING STATION

1 - 1-1/2" Fisher type 667, DBQ WC6 body, 2500# PSIG reducing valve with 4100UR Controller and S.O. valve, type 667 operator with 3560A positioner, Consolidated Fig. safety valve, handjack, discharge elbow, mounting tee, fittings, etc.

TO BE PROVIDED BY OTHERS

a. Support plates and sleeves to attach blowers to boiler and furnace walls.

b. Structural supports for IK Units.

c. Source of suitable electric current, as stated in quotation.

d. Electric wiring to interconnect blowers, panel, push button stations, motor starters, and source of electric current.

e. Labor, supervision, scaffolding, rigging and other costs incidental to installation of proposed boiler cleaning equipment.

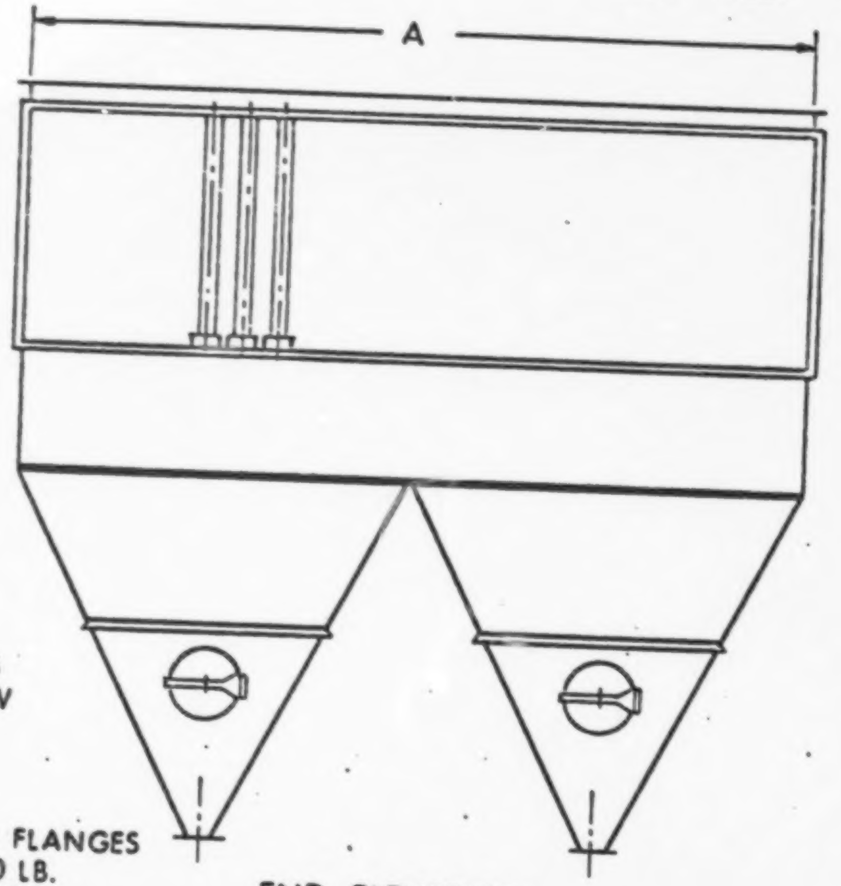
f. Sealing and aspirating air piping from source of supply to individual blower pressure seals.

DUST COLLECTOR

The Corporation will furnish one (1) mechanical dust collector Type 104BWHS-22-21-12 manufactured by UOP Air Correction Division or equivalent as described on the following pages.

The dust collector will be of the mechanical type designed for an overall efficiency of 83% on the basis of a fly ash analysis with not more than 30% less than 10 microns in size. The maximum loss through the collector at 3,500,000 lb/hr boiler capacity will not exceed 2.9" H_2O. The hopper capacity will be sufficient for hour ash storage with an ash density of lb/cu. ft.

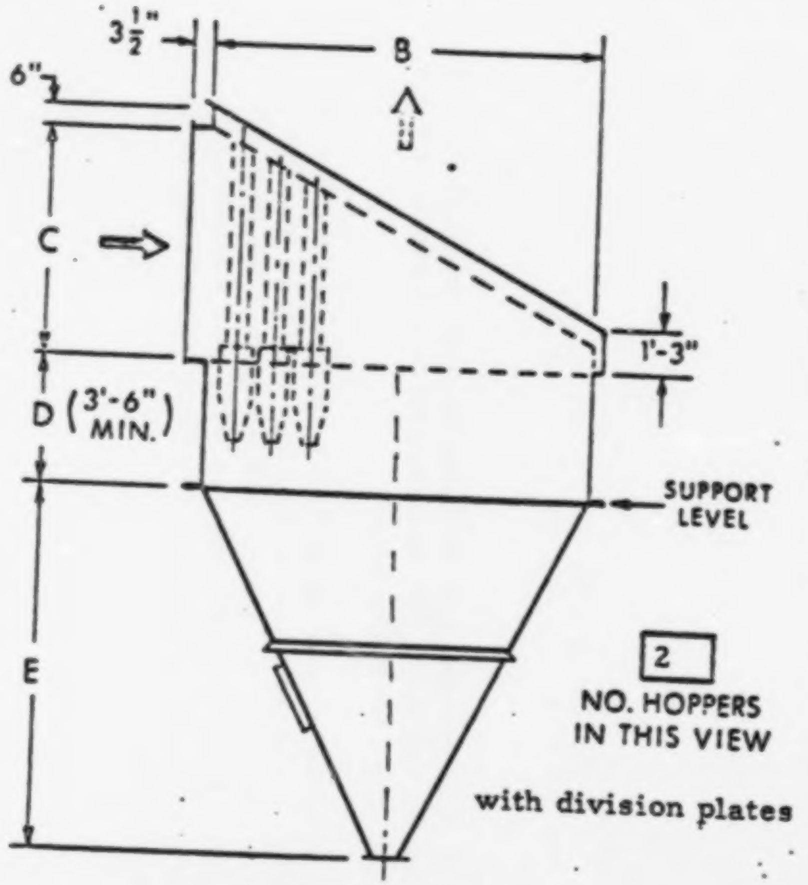
SIDE INLET – TOP OUTLET



12
NO. HOPPERS
IN THIS VIEW

NOTE:
STD. HOPPER FLANGES
MATCH 8" 150 LB.
ASA DRILLING

END ELEVATION



2
NO. HOPPERS
IN THIS VIEW

with division plates

SIDE ELEVATION

DESIGNATION	DIMENSIONS (FEET & INCHES)					WEIGHT		DUST CAP.
DESIGN	A	B	C	D	E	WITHOUT DUST LOAD	WITH DUST LOAD	CU. FT.
104BWHS-22-2112	100-0	23-0	13-3	3-6	9-8	395,000		7920

NOT FOR CONSTRUCTION – DIMENSIONS APPROXIMATE ONLY

COLLECTOR SUPPORTS MOUNTED ON CASING, SUPPLIED BY MANUFACTURER
STRUCTURAL STEEL, ON WHICH COLLECTOR SUPPORTS REST, SUPPLIED BY OTHERS

UOP AIR CORRECTION
DIVISION

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FORM NO. 3-062

DESIGN 100 SERIES TUBULAR DUST COLLECTOR
DIMENSION SKETCH

BY:	DATE:	FILE: 001-1359	SK. NO. A

TERMINAL POINTS - PART I

The equipment furnished by the Corporation will terminate at the following points beyond which connections and equipment are to be furnished by the Purchaser:

Major Pressure Part Terminal Points:	Number	Size	Type	Arrangement
Superheater Outlet	1	18.75" ID		Center Discharge
Reheater #1 Inlet	1	28" ID		Single End
" #1 Outlet	1	34" ID		Single End
Reheater #2 Inlet				
" #2 Outlet				
Economizer Inlet	1	16" OD		Single End

1. Superheater Outlet, Reheater Inlet, Reheater Outlet and Economizer Nozzles will terminate immediately outside of the steam generator casing.
2. Safety Valves will terminate at valve discharge flange.

3. Feed stop and check valves will be located in Purchaser's piping.
4. Economizer Hopper will terminate at Outlet Flange.
5. Drain and Sampling Connections will terminate at main operating floor level.
6. Flues and Ducts will terminate the force draft fan discharge on the air side and at dust collector inlet flange on the gas side.
7. Thermocouples will terminate at common junction boxes adjacent to the boiler casing.

8. Dust Collector will terminate at the flue gas outlet flanges and at the outlet flanges of their hoppers.
9. Sealing Air will be manifolded and piped to F.D. fan.
10. Aspirating Air Piping will terminate in one connection located at the basement level.
11. Electrical Equipment will be furnished without wiring or controls, unless specifically described in this proposal.

TERMINAL POINTS - PART II

The equipment furnished by the Corporation will terminate at the following points beyond which connections and equipment are to be furnished by the Purchaser:

A. For Solid Fuel Fired Units:

1. FURNACE HOPPER will terminate at the hopper seal castings
2. FLY ASH HOPPERS will terminate at the outlet flange
3. RAW COAL CONNECTION to Purchaser's equipment will be at the feeder inlet

STEAM GENERATING UNIT PERFORMANCE AND GENERATING CONDITIONS - PART I

Performance data for the equipment covered are submitted and made a part of this proposal in accordance with the recommendations of the American Boiler Manufacturers Association.

It is recognized that the performance of the equipment covered in this proposal cannot be exactly predicted for every possible operating condition. In consequence, any predicted performance data submitted are intended to show probable operating results which may be closely approximated but which cannot be guaranteed except as expressly stated in the guarantee clause or clauses in this proposal.

Any performance curves submitted are for the Purchaser's convenience and the performance indicated thereon is not offered by the Corporation, nor to be construed by the Purchaser, as a proposal or contract obligation.

The general arrangement of equipment furnished by the Corporation, and the general design and arrangement of related equipment furnished by others, shall be not less favorable than indicated on the proposal drawing identified on the Summary Performance Sheet herein.

The equipment shall have been erected in accordance with the Corporation's plans and specifications, properly maintained and operated by the Purchaser, and shall be in operating condition satisfactory to the Corporation. The heat absorbing surfaces shall be clean inside and out.

There shall be sufficient forced and/or induced draft fan capacity available to provide the necessary air for combustion at a pressure at the burner windbox to overcome all of the resistance through the unit including the breeching and stack. Means shall be provided to control the flow of the supply of air and of the flue gases down to minimum ratings.

Ambient air conditions:

Temperature of boiler room air	F	80
Relative humidity of boiler room air	%	60
Barometric pressure	in. hg.	29.921
Weight of water per lb of air	lb.	0.013

The fuel characteristics shall not be less favorable than that indicated for the fuel or fuels listed on the Summary Performance Sheet herein.

Operating conditions shall be as stated on the Summary Performance Sheet herein.

Measurements of CO_2 or other properties of the combustion gases in furnace or convection passes shall be determined by sampling uniformly across the width of the unit. No performance tests shall be made unless combustion equipment and the combustion process are functioning normally.

STEAM GENERATING UNIT PERFORMANCE AND GUARANTEE CONDITIONS - PART II

The condition of the concentrated boiler water shall be as shown in the following table for the applicable operating pressure:

Pressure at Outlet of Steam Generating Unit — psig	Total Solids ppm	Total Alkalinity ppm	Suspended Solids ppm
0 - 300	3500	700	300
301 - 450	3000	600	250
451 - 600	2500	500	150
601 - 750	2000	400	100
751 - 900	1500	300	60
901 - 1000	1250	250	40
1001 - 1500	1000	200	20
1501 - 2000	750	150	10
2001 - and higher	500	100	5

The treatment of feed water and the conditioning of boiler water are beyond the control of the Corporation. Therefore, the Corporation shall not be held responsible for damage due to the presence of oil, grease, scale or deposits on the internal surfaces of the equipment; or for damage resulting from foaming caused by chemical conditions of the water, or for damage resulting from corrosion or caustic embrittlement. The Corporation shall not be responsible for carryover resulting from the presence of oil, grease or other contaminating material.

WATER AND STEAM SAMPLING CONDITIONS

Samples of water for testing shall be taken from the continuous blowdown, or from a suitably located sampling pipe, through a cooling coil to prevent flashing. Sampling and determination of boiler water conditions shall be under the methods contained in ASTM Special Technical Publication No. 148.

Samples of condensed steam for determination of solids shall be obtained in accordance with the method specified in the latest edition of ASTM-D-1066, Tentative Method for Sampling Steam.

Solids in the steam sample may be determined by either of the two methods described below:

If the electrical conductivity determination of dissolved solids in the condensed steam is used, it shall be made in accordance with ASTM-D-1125-59, Tentative Method on Electrical Conductivity of Water. Remove dissolved gases from the sample as completely as possible by mechanical means without contaminating the sample with any added material which will increase its conductivity. The conductivity shall be corrected to compensate for residual ammonia, carbon dioxide or other gases remaining in the sample and the dissolved solids shall be calculated from this corrected conductivity. For measuring performance by the electrical conductivity method, the average of ten determinations made at regular intervals throughout the test period shall be used.

If the gravimetric determination of total solids in the condensed steam is used, it may be made in accordance with Method A of the latest edition of ASTM-D-1069, Tests for Suspended and Dissolved Solids in Industrial Waters, or a similar method embodying the essential principles of that specification. For measuring performance by the gravimetric method, the results shall be expressed as the average of three determinations made upon a composite sample which shall be taken throughout the entire test period.

INSPECTION, TEST AND WARRANTY CONDITIONS

Each steam generator will be built in accordance with ASME Boiler Code for working pressure specified on Summary Performance Sheet herein. The Corporation will furnish the Purchaser with a certificate from an authorized boiler inspection and insurance company stating that the steam generator is safe for the design working pressure specified above and conforms with the ASME Boiler Code. The Corporation will pay for shop inspection.

Field inspection by the insurance company shall be paid for by the Purchaser unless the erection of the equipment is to be performed by the Corporation.

When erection is completed, but before installation of the setting, the steam generator shall be tested and made tight by the erection contractor at an hydrostatic pressure one and a half times design pressure. The Purchaser shall provide the water required for said test and introduce same into the boilers when they are ready for test and shall also provide drainage from blow-off when test has been completed.

When a tightness test is required for the furnace enclosure and the steam generator gas passages, the openings of the unit shall be blanked and air shall be admitted until the internal pressure reaches 20 in. W.G. The unit shall then be sealed and, if the pressure drop does not exceed 5.0 in. W.G. in ten minutes, the unit shall be considered acceptably tight.

Performance tests, if required, and performance calculations shall be in accordance with the applicable Short Test Form in the latest edition of the ASME Test Code for Stationary Steam Generating Units, and the measure of performance shall be the results of such tests. Performance calculations shall be based on the steam tables in the latest edition of "Thermodynamic Properties of Steam" by Keenan and Keyes.

Performance tests, of the steam generator or any of the equipment furnished by the Corporation, if required, shall be run within sixty days after the Purchaser shall have received notice from the Corporation that the equipment furnished is ready for testing, it being understood that the Corporation may require preliminary tests. Tests shall be conducted only on one representative unit mutually agreed upon by the Purchaser and the Corporation. The Purchaser, at his own expense, shall make all preparations, furnish all operating and testing personnel and incur all expenses connected with such tests, and shall give to the Corporation at least fifteen days' notice of the date or dates on which tests will be made.

The Corporation's representative shall have access to the records at all times, and the test shall be conducted in a manner to satisfy the Corporation that the specified performance conditions are being maintained. A complete copy of test data and results shall be furnished to the Corporation.

The equipment shall be considered as accepted if tests show that the guarantees have been fulfilled, or if the Purchaser shall fail to have said equipment tested within period herein specified. In case of failure to meet performance guarantees, the Corporation reserves the right to change or replace the equipment furnished so that guaranteed performance will be obtained.

The Corporation assumes no responsibility for damage to boilers or other equipment furnished by it, resulting from improper operation or introduction of improper substances to their interiors.

TABLE D-1

CHEMICAL ANALYSIS OF ASH BLENDED WITH COAL AND PYRITES

CHEMICAL ANALYSIS	SAMPLE 1	SAMPLE 2
Al_2O_3	15.0	14.5
SiO_2	25.0	17.0
TiO	0.50	0.8
Fe_2O_3	8.5	3.25
CaO	28.5	13.0
K_2O	0.48	6.88
Na_2O	3.6	3.37
MgO	7.4	3.19
P_2O_5	3.45	0.57
SO_3	10.0	32.17

ASH FUSION

Reducing Atmosphere

Initial Deformation	2240	2380
Softening Temperature	2350	2440
Fluid Temperature	2600	2560

Sample 1 was mixed with blends; 2A, 2B, 2C,
3A, 3B, 3C,
4A, 4B, 4C.

Sample 2 was mixed with blends; 1A, 1B, 1C,
5A, 5B, 5C.

TABLE D-2

FINAL COMPOSITION
OF BLENDS EXPRESSED
AS PERCENT PYRITES, COAL AND ASH

	PERCENT			
SAMPLE NUMBER	ASH(4)	PYRITES(1)	COAL	TOTAL ASH(3)
1A(2)	32.5	16.5	51	36.4
1B	27	17	56	29.7
1C	34	14	52	35.8
2A	19	35	46	39.1
2B	27	32	41	50.4
2C	34	29	37	53.4
3A	20	50	30	54.8
3B	28	45	27	58.0
3C	35	40	25	65.6
4A	17	66	17	61.6
4B	28	57	15	67.3
4C	35	51	14	71.2
5A	5	80	15	55.3
5B	10	76	14	55.1
5C	15	71	14	58.0

(1) Percent includes small quantities of ash and carbon left in cleaned pyrites. Refer to analysis of cleaned pyrites.

(2) An error was made in the initial blending of the ash.

(3) Non pyritic ash plus pyritic ash as analyzed.

(4) Non pyritic ash.

TABLE D-3

FUEL ANALYSIS FOR BLENDS OF ASH, COAL AND PYRITES

SAMPLE NO. Coal* ASH† - COAL 100 PYRITES -

PROXIMATE ANALYSIS

	As Received	Dry
% Fixed Carbon	81.70	81.96
% Volatile Matter	16.18	16.23
% Ash	1.80	1.81
% Moisture	0.23	-
TOTAL	100.00	100.00
Air Dry Loss	NIL	

ULTIMATE ANALYSIS

	Dry
% C	89.47
% H	4.60
% O	2.64
% N	0.94
% S	0.54
% Ash	1.81
% Moisture	-
TOTAL	100.00

HARDGROVE INDEX

97.13

REACTIVITY

Reactivity Index, T_{15} °C	266
Energy of Activation	

HEATING VALUE, BTU/LB

As Received	15,421
Dry	15,470

ASH FUSION °F

	Reducing Atmosphere	Oxidizing Atmosphere
Initial Deformation	2440	2460
Softening Temperature SPH	2500	2500
Softening Temperature HEM	2510	2530
Fusion Temperature	2530	2540

* Pochahantos Coal

† Non Pyritic

TABLE D-4

FUEL ANALYSIS FOR
BLENDS OF ASH, COAL AND PYRITES

SAMPLE NO. Pyrites ASH - COAL - PYRITES 100%

PROXIMATE ANALYSIS

	As Received	Dry
% Fixed Carbon	10.99	11.03
% Volatile Matter	25.37	25.47
% Ash	63.25	63.50
% Moisture	0.39	-
TOTAL	100.00	100.00
Air Dry Loss	NIL	

ULTIMATE ANALYSIS

	Dry
% C	5.25
% H	0.44
% O	-
% N	0.03
% S	40.41
% Ash	63.50
% Moisture	-
TOTAL	109.63

HARDGROVE INDEX

44.99

REACTIVITY

Reactivity Index, T_{15} °C	299

HEATING VALUE, BTU/LB

As Received	2,506
Dry	2,512

ASH FUSION °F

	Reducing Atmosphere	Oxidizing Atmosphere
Initial Deformation	2490	2500
Softening Temperature SPH	2560	2580
Softening Temperature HEM	2640	2690
Fusion Temperature	2680	2730

TABLE D-5

FUEL ANALYSIS FOR BLENDS OF ASH, COAL AND PYRITES

SAMPLE NO. 1A ASH * 32.5/36.4 COAL 51 PYRITES 16.5 △

PROXIMATE ANALYSIS

	As Received	Dry
% Fixed Carbon	39.53	40.13
% Volatile Matter	23.09	23.44
% Ash	35.88	36.43
% Moisture	1.50	-
TOTAL	100.00	100.00
Air Dry Loss	NIL	

ULTIMATE ANALYSIS

	Dry
% C	47.60
% H	2.46
% O	4.45
% N	0.43
% S	8.63
% Ash	36.43
% Moisture	-
TOTAL	100.00

HARDGROVE INDEX

88.43

REACTIVITY

Reactivity Index, T_{15} °C 296

HEATING VALUE, BTU/LB

As Received	8,108
Dry	8,231

ASH FUSION °F

	Reducing Atmosphere	Oxidizing Atmosphere
Initial Deformation	2150	2240
Softening Temperature SPH	2210	2270
Softening Temperature HEM	2240	2350
Fusion Temperature	2340	2420

*Non Pyritic/Total Ash

TABLE D-6

FUEL ANALYSIS FOR BLENDS OF ASH, COAL AND PYRITES

SAMPLE NO. 1B ASH* 27/29.7 COAL 56 PYRITES 17

PROXIMATE ANALYSIS

	As Received	Dry
% Fixed Carbon	48.64	49.10
% Volatile Matter	20.94	21.14
% Ash	29.48	29.76
% Moisture	0.94	-
TOTAL	100.00	100.00
Air Dry Loss	NIL	

ULTIMATE ANALYSIS

	Dry
% C	55.34
% H	2.84
% O	2.06
% N	0.61
% S	9.39
% Ash	29.76
% Moisture	-
TOTAL	100.00

HARDGROVE INDEX

89.74

REACTIVITY

Reactivity Index, T_{15} °C 289

HEATING VALUE, BTU/LB

As Received	9,548
Dry	9.639

ASH FUSION °F

	Reducing Atmosphere	Oxidizing Atmosphere
Initial Deformation	2190	2290
Softening Temperature SPH	2300	2370
Softening Temperature HEM	2350	2430
Fusion Temperature	2480	2530

*Non Pyritic Ash/Total Ash

TABLE D-7

FUEL ANALYSIS FOR BLENDS OF ASH, COAL AND PYRITES

SAMPLE NO. 1C ASH* 34/35.8 COAL 52 PYRITES 14 △

PROXIMATE ANALYSIS

	As Received	Dry
% Fixed Carbon	40.33	40.81
% Volatile Matter	23.06	23.34
% Ash	35.42	35.85
% Moisture	1.19	-
TOTAL	100.00	100.00
Air Dry Loss	NIL	

ULTIMATE ANALYSIS

	Dry
% C	47.39
% H	2.46
% O	3.19
% N	0.58
% S	10.53
% Ash	35.85
% Moisture	-
TOTAL	100.00

HARDGROVE INDEX	90.06

REACTIVITY

Reactivity Index, T_{15} °C	293

HEATING VALUE, BTU/LB

As Received	8,377
Dry	8,478

ASH FUSION °F

	Reducing Atmosphere	Oxidizing Atmosphere
Initial Deformation	2170	2250
Softening Temperature SPH	2220	2290
Softening Temperature HEM	2250	2390
Fusion Temperature	2360	2480

*Non Pyritic Ash/Total Ash

TABLE D-8

FUEL ANALYSIS FOR BLENDS OF ASH, COAL AND PYRITES

SAMPLE NO. 2A ASH* 19/39.1 COAL 46 PYRITES 35

PROXIMATE ANALYSIS

	As Received	Dry
% Fixed Carbon	44.19	44.34
% Volatile Matter	16.56	16.61
% Ash	38.92	39.05
% Moisture	0.33	-
TOTAL	100.00	100.00
Air Dry Loss	NIL	

ULTIMATE ANALYSIS

	Dry
% C	49.32
% H	2.42
% O	-
% N	0.43
% S	13.17
% Ash	39.05
% Moisture	-
TOTAL	104.39

HARDGROVE INDEX

99.40

REACTIVITY

Reactivity Index, T_{15} °C	282

HEATING VALUE, BTU/LB

As Received	9,059
Dry	9,089

ASH FUSION °F

	Reducing Atmosphere	Oxidizing Atmosphere
Initial Deformation	2220	2310
Softening Temperature SPH	2320	2440
Softening Temperature HEM	2360	2520
Fusion Temperature	2560	2640

*Non Pyritic Ash/Total Ash

TABLE D-9

FUEL ANALYSIS FOR
BLENDS OF ASH, COAL AND PYRITES

SAMPLE NO. 2B ASH 27/50.4 COAL 41 PYRITES 32

PROXIMATE ANALYSIS	As Received	Dry
% Fixed Carbon	29.51	29.54
% Volatile Matter	19.99	20.01
% Ash	50.39	50.45
% Moisture	0.11	-
TOTAL	100.00	100.00
Air Dry Loss	NIL	

ULTIMATE ANALYSIS	Dry
% C	40.53
% H	1.87
% O	-
% N	0.41
% S	11.71
% Ash	50.45
% Moisture	-
TOTAL	104.97
HARDGROVE INDEX	110.42
REACTIVITY	
Reactivity Index, T_{15} °C	296
HEATING VALUE, BTU/LB	
As Received	6,900
Dry	6,908

ASH FUSION °F	Reducing Atmosphere	Oxidizing Atmosphere
Initial Deformation	2020	2290
Softening Temperature SPH	2080	2430
Softening Temperature HEM	2120	2480
Fusion Temperature	2280	2620

TABLE D-10

FUEL ANALYSIS FOR BLENDS OF ASH, COAL AND PYRITES

SAMPLE NO. 2C ASH* 34/53.4 COAL 37 PYRITES 2.9

PROXIMATE ANALYSIS

	As Received	Dry
% Fixed Carbon	26.92	26.93
% Volatile Matter	19.62	19.62
% Ash	53.44	53.45
% Moisture	0.02	-
TOTAL	100.00	100.00
Air Dry Loss	NIL	

ULTIMATE ANALYSIS

	Dry
% C	33.64
% H	1.71
% O	-
% N	0.39
% S	15.05
% Ash	53.45
% Moisture	-
TOTAL	104.24

HARDGROVE INDEX	116.23

REACTIVITY

Reactivity Index, T_{15} °C	294

HEATING VALUE, BTU/LB

As Received	6,342
Dry	6,342

ASH FUSION °F

	Reducing Atmosphere	Oxidizing Atmosphere
Initial Deformation	2030	2310
Softening Temperature SPH	2110	2440
Softening Temperature HEM	2140	2490
Fusion Temperature	2310	2620

*Non Pyritic Ash/Total Ash

TABLE D-11

FUEL ANALYSIS FOR BLENDS OF ASH, COAL AND PYRITES

SAMPLE NO. 3A ASH* 20/54.8 COAL 30 PYRITES 50

PROXIMATE ANALYSIS

	As Received	Dry
% Fixed Carbon	24.56	24.58
% Volatile Matter	20.54	20.55
% Ash	54.84	54.87
% Moisture	0.06	-
TOTAL	100.00	100.00
Air Dry Loss	NIL	

ULTIMATE ANALYSIS

	Dry
% C	29.23
% H	1.40
% O	-
% N	0.29
% S	22.11
% Ash	54.87
% Moisture	-
TOTAL	107.90

HARDGROVE INDEX	98.15

REACTIVITY

Reactivity Index, T_{15} °C	294

HEATING VALUE, BTU/LB

As Received	5,805
Dry	5,808

ASH FUSION °F

	Reducing Atmosphere	Oxidizing Atmosphere
Initial Deformation	2200	2260
Softening Temperature SPH	2360	2430
Softening Temperature HEM	2420	2500
Fusion Temperature	2500	2610

*Non Pyritic Ash/Total Ash

TABLE D-12

FUEL ANALYSIS FOR BLENDS OF ASH, COAL AND PYRITES

SAMPLE NO. 3B ASH* 28/58 COAL 27 PYRITES 45

PROXIMATE ANALYSIS

	As Received	Dry
% Fixed Carbon	21.57	21.59
% Volatile Matter	20.39	20.41
% Ash	57.94	58.00
% Moisture	0.10	-
TOTAL	100.00	100.00
Air Dry Loss	NIL	

ULTIMATE ANALYSIS

	Dry
% C	27.94
% H	1.27
% O	-
% N	0.32
% S	21.62
% Ash	58.00
% Moisture	-
TOTAL	109.20

HARDGROVE INDEX	100.02

REACTIVITY

Reactivity Index, T_{15} °C	309

HEATING VALUE, BTU/LB

As Received	5,220
Dry	5,225

ASH FUSION °F

	Reducing Atmosphere	Oxidizing Atmosphere
Initial Deformation	2210	2280
Softening Temperature SPH	2350	2400
Softening Temperature HEM	2440	2490
Fusion Temperature	2560	2610

*Non Pyritic Ash/Total Ash

TABLE D-13

FUEL ANALYSIS FOR
BLENDS OF ASH, COAL AND PYRITES

SAMPLE NO. 3C ASH* 35/65.6 COAL 25 PYRITES 40 △

PROXIMATE ANALYSIS	As Received	Dry
% Fixed Carbon	13.09	13.13
% Volatile Matter	21.24	21.28
% Ash	65.46	65.59
% Moisture	0.21	-
TOTAL	100.00	100.00
Air Dry Loss	NIL	

ULTIMATE ANALYSIS	Dry
% C	24.17
% H	1.55
% O	-
% N	0.24
% S	18.04
% Ash	65.59
% Moisture	-
TOTAL	109.59

HARDGROVE INDEX	107.07

REACTIVITY

Reactivity Index, T_{15} °C	299

HEATING VALUE, BTU/LB

As Received	4,350
Dry	4,359

ASH FUSION °F	Reducing Atmosphere	Oxidizing Atmosphere
Initial Deformation	2260	2240
Softening Temperature SPH	2290	2310
Softening Temperature HEM	2300	2360
Fusion Temperature	2310	2400

*Non Pyritic Ash/Total Ash

TABLE D-14

FUEL ANALYSIS FOR BLENDS OF ASH, COAL AND PYRITES

SAMPLE NO. 4A ASH* 17/61.6 COAL 17 PYRITES 66

PROXIMATE ANALYSIS

	As Received	Dry
% Fixed Carbon	16.46	16.49
% Volatile Matter	21.78	21.83
% Ash	61.54	61.68
% Moisture	0.22	-
TOTAL	100.00	100.00
Air Dry Loss	NIL	

ULTIMATE ANALYSIS

	Dry
% C	21.68
% H	1.12
% O	-
% N	0.21
% S	29.71
% Ash	61.68
% Moisture	-
TOTAL	114.40

HARDGROVE INDEX	89.46

REACTIVITY

Reactivity Index, T_{15} °C	302

HEATING VALUE, BTU/LB

As Received	3,868
Dry	3,877

ASH FUSION °F

	Reducing Atmosphere	Oxidizing Atmosphere
Initial Deformation	2480	2480
Softening Temperature SPH	2510	2510
Softening Temperature HEM	2540	2560
Fusion Temperature	2800+	2800+

*Non Pyritic Ash/Total Ash

TABLE D-15

FUEL ANALYSIS FOR BLENDS OF ASH, COAL AND PYRITES

SAMPLE NO. 4B ASH* 28/67.3 COAL 15 PYRITES 57

PROXIMATE ANALYSIS

	As Received	Dry
% Fixed Carbon	11.38	11.41
% Volatile Matter	21.21	21.25
% Ash	67.20	67.34
% Moisture	0.21	-
TOTAL	100.00	100.00
Air Dry Loss	NIL	

ULTIMATE ANALYSIS

	Dry
% C	20.03
% H	0.98
% O	-
% N	0.17
% S	18.44
% Ash	67.34
% Moisture	-
TOTAL	106.96

HARDGROVE INDEX	96.66

REACTIVITY

Reactivity Index, T_{15} °C	305

HEATING VALUE, BTU/LB

As Received	3,531
Dry	3,538

ASH FUSION °F

	Reducing Atmosphere	Oxidizing Atmosphere
Initial Deformation	2460	2470
Softening Temperature SPH	2480	2500
Softening Temperature HEM	2520	2580
Fusion Temperature	2800+	2800+

*Non Pyritic Ash/Total Ash

TABLE D-16

FUEL ANALYSIS FOR
BLENDS OF ASH, COAL AND PYRITES

SAMPLE NO. 4C ASH* 35/71.2 COAL 14 PYRITES 51 △

PROXIMATE ANALYSIS	As Received	Dry
% Fixed Carbon	6.84	6.87
% Volatile Matter	21.77	21.85
% Ash	71.01	71.28
% Moisture	0.38	-
TOTAL	100.00	100.00
Air Dry Loss	NIL	

ULTIMATE ANALYSIS	Dry
% C	18.67
% H	0.80
% O	-
% N	0.16
% S	11.34
% Ash	71.28
% Moisture	-
TOTAL	102.25
HARDGROVE INDEX	102.50
REACTIVITY	
Reactivity Index, T_{15} °C	299
HEATING VALUE, BTU/LB	
As Received	2,983
Dry	2,994

ASH FUSION °F	Reducing Atmosphere	Oxidizing Atmosphere
Initial Deformation	2295	2300
Softening Temperature SPH	2360	2380
Softening Temperature HEM	2390	2460
Fusion Temperature	2520	2540

*Non Pyritic Ash/Total Ash

TABLE D-17

FUEL ANALYSIS FOR
BLENDS OF ASH, COAL AND PYRITES

SAMPLE NO. 5A ASH* 5/55.3 COAL 15 PYRITES 80

PROXIMATE ANALYSIS	As Received	Dry
% Fixed Carbon	19.90	19.99
% Volatile Matter	24.57	24.69
% Ash	55.06	55.32
% Moisture	0.47	-
TOTAL	100.00	100.00
Air Dry Loss	NIL	

ULTIMATE ANALYSIS	Dry
% C	22.99
% H	0.91
% O	-
% N	0.21
% S	27.08
% Ash	55.32
% Moisture	-
TOTAL	106.51

HARDGROVE INDEX	64.32
REACTIVITY	
Reactivity Index, T_{15} °C	295
HEATING VALUE, BTU/LB	
As Received	4,148
Dry	4,167

ASH FUSION °F	Reducing Atmosphere	Oxidizing Atmosphere
Initial Deformation	2400	2580
Softening Temperature SPH	2450	2680
Softening Temperature HEM	2570	2700
Fusion Temperature	2620	2800+

*Non Pyritic Ash/Total Ash

TABLE D-18

FUEL ANALYSIS FOR BLENDS OF ASH, COAL AND PYRITES

SAMPLE NO. 5B ASH* 10/55.1 COAL 14 PYRITES 76 ◊

PROXIMATE ANALYSIS

	As Received	Dry
% Fixed Carbon	19.44	19.53
% Volatile Matter	25.24	25.36
% Ash	54.86	55.11
% Moisture	0.46	-
TOTAL	100.00	100.00
Air Dry Loss	NIL	

ULTIMATE ANALYSIS

	Dry
% C	23.45
% H	1.06
% O	-
% N	0.21
% S	28.68
% Ash	55.11
% Moisture	-
TOTAL	108.51

HARDGROVE INDEX 67.03

REACTIVITY

Reactivity Index, T_{15} °C 299

HEATING VALUE, BTU/LB

As Received	4,410
Dry	4,430

ASH FUSION °F

	Reducing Atmosphere	Oxidizing Atmosphere
Initial Deformation	2400	2400
Softening Temperature SPH	2450	2480
Softening Temperature HEM	2570	2600
Fusion Temperature	2630	2690

*Non Pyritic Ash/Total Ash

TABLE D-19

FUEL ANALYSIS FOR BLENDS OF ASH, COAL AND PYRITES

SAMPLE NO. 5C ASH* 15/58.0 COAL 14 PYRITES 71

PROXIMATE ANALYSIS

	As Received	Dry
% Fixed Carbon	15.32	15.44
% Volatile Matter	25.55	25.76
% Ash	58.32	58.80
% Moisture	0.81	-
TOTAL	100.00	100.00
Air Dry Loss	NIL	

ULTIMATE ANALYSIS

	Dry
% C	21.77
% H	1.03
% O	-
% N	0.17
% S	31.15
% Ash	58.80
% Moisture	-
TOTAL	112.92

HARDGROVE INDEX

69.95

REACTIVITY

Reactivity Index, T_{15} °C	301

HEATING VALUE, BTU/LB

As Received	3,247
Dry	3,274

ASH FUSION °F

	Reducing Atmosphere	Oxidizing Atmosphere
Initial Deformation	2130	2590
Softening Temperature SPH	2380	2680
Softening Temperature HEM	2410	2760
Fusion Temperature	2480	2800+

*Non Pyritic Ash/Total Ash

XII

ASH

1. PRODUCTION AND OUTLOOK

The high sulfur combustor as an adjunct to coal cleaning is, almost by definition, a voluminous producer of ash. Both CASE A and CASE B, for example, have to cope with a large share of the ash from eight to ten million tons per year ROM coal. If this ROM is similar to Ohio #6, Columbiana County, Ohio which contains about 15% total ash (see Table II-4), the associated high sulfur combustor may need to handle as much as two-thirds of this total ash or 800, 000 to 1, 000, 000 tons per year. Dumping of this quantity of ash will be a substantial cost burden at best, but so large a tonnage at one point may actually improve the chance of realizing on useful applications. By comparison 17 million tons of flyash were collected in the United States in 1966, 18 million in 1967, 20 in 1968 and 22 in 1969. By 1975 production of this typically waste material is estimated at nearly 30 million tons annually and by 1980, 35 to 40 million tons. To these numbers, bottom ash and boiler slag must be added increasing flyash figures perhaps by 50%. As for the long term, it is likely that new coal-fired power plants will exceed other types in number and capacity for decades ahead.

Useful application of flyash in this country is still less than 10% of that produced. (See Appendix XII-B). The European nations have realized much greater relative application, more than half of output in several instances, in products ranging from bricks to soil stabilizers.

1.1 Dumping costs in the United States are said to range from \$1.00 to \$2.00 per ton and expected to become steadily more costly. In the operating cost estimates of Part VIII ash disposal (dumping) is charged at \$2.00 per ton. Dumping cost in Europe is substantially higher on the average.

1.2 High iron ash is a possible source of iron oxide (Fe_2O_3) for recovery of iron via the blast furnace (See Part XII-4). The iron content of ashes from the four HSC Fuels considered in this study is in the range 20 to 30% for the high energy fuels (CASE E and D) and 40 to 50% for the low energy fuels (CASE B and A). The iron content of ROM bituminous coal ash in the United States varies all the way from 1% to 30%, and the average iron content of commercial steam coals is probably less than 20%, although iron may tend to increase with increasing sulfur content. In any event some reservation is in order concerning the suitability of HSC ashes for all applications mentioned in the literature and as discussed below.

2. CURRENT MARKETS
(See also Bibliography in APPENDIX XII-A)

Tables XII-1 and XII-2 summarize ash output by the U.S. Electric Industry, and usage, in 1969. The marketing of flyash is attended by difficulties and slowly growing success.

2.1 Asphalt Paving

Flyash in this use is principally employed to make up a deficiency in the fine aggregate. Nearly all asphalt is utilized in roadway construction of some kind. Tests conducted as early as 1931 demonstrated that a satisfactory wearing surface could be developed with flyash as a mineral filler in asphalt in lieu of limestone dust, lime or Portland cement theretofore used. In 1939 approval was obtained from certain highway authorities for application of flyash in this manner, in which it enjoyed a distinct price advantage over competitive products. However, specifications are strict, demand varies seasonally, and shipping is costly. State highway agencies, the major users of asphalt paving, require laboratory acceptance and field testing, usually over several years, before a new technique or material is admitted to specifications. General acceptance for this use is still years away.

TABLE XII-1
ASH COLLECTION AND UTILIZATION DURING 1969
(PRELIMINARY FIGURES)

	Fly Ash Tons	Bottom Ash Tons	Boiler Slag (If separated from Bottom Ash) Tons
1. TOTAL ASH COLLECTED	22,304,513	8,042,017	3,020,282
2. ASH UTILIZED			
a. Mixed with cement clinker or cement (pozzolan cement)	32,759	-	-
b. Mixed with raw material before forming cement clinker	132,226	5,000	-
c. Partial replacement of cement in:			
1. Concrete products	175,086	5,686	-
2. Structural concrete	194,322	-	-
3. Dams and other mass concrete	163,809	-	-
d. Stabilizer for road bases, parking areas, etc.	264,224	20,617	73,240
e. Lightweight aggregate	250,251	19,388	-
f. Fill material for roads, construction sites, etc.	73,440	1,102,240	548,606
g. Filler in asphalt mix	114,067	10,084	89,970
h. Miscellaneous (See Table II)	244,508	648,052	257,204
TOTAL ITEM #2	1,644,692	1,811,067	969,020
3. Ash removed from plant sites at no cost to utility but not covered in categories listed under "Ash Utilization"	452,522	381,076	48,387
TOTAL UTILIZED, ITEMS #2 & #3	2,097,214	2,192,143	1,017,407

Source: Second Ash Utilization Symposium, Pittsburgh, Pa.; March 10-11, 1970

TABLE XII-2

MISCELLANEOUS USES OF ASH, 1969 (PRELIMINARY FIGURES)

	Fly Ash Tons	Bottom Ash Tons	Boiler Slag Tons
Abrasive Cleaning	34		19,344
Test Caps	3		
Refractory Add-Mix	80		
Experimental - Ready Mix Supplier	62		
Insulating Cement	702		
Oil Well Cementing	81,427		
Grouting	3,832		
Industrial Tests	150		
Snow Sanding	800		
Mine Fire Control	60,772		
Unclassified	5,983	1,620	26,266
Subsidence Control	31,750		
Pipe Coating	1,445		
Foundry Sand	1,550		
Chemical Products	250		
Commercial Ready Mix	2,143		
Foundries - Manufactured Products	2,300		
Spontaneous Combustion Control	32,000	32,000	
Oil Well Drilling	1,570		
Highway Bridges	11,361		
Sewage Treatment Plant	3,000		
Subsurface Heavy Construction	2,819		
Poz-O-Pac	475		
Vanadium Content		15	273
Ice Control		441,039	34,567
School Use on Outdoor Tracks		1,000	
Asphalt Shingles		108,877	5,033
Sandblasting Grit		38,902	128,843
Dike Repair and Build-up		21,813	
Drainage Filter		2,786	200
Aggregate			42,678
TOTAL	244,508	648,052	257,204

Source: Second Ash Utilization Symposium, Pittsburgh, Pa.; March 10-11, 1970

2.2 Concrete

Flyash in concrete mixes serves two general purposes. As a fine material it supplements or replaces other fine mechanical fillers in the aggregate. As a pozzolan, it reacts chemically with the free lime to form cementitious material adding to the activity of Portland cement.

Wherever ash for concrete can be purchased under specification and put to a controlled use, the outlook for growth of demand improves. Major construction jobs such as dams, and road building are of this type but the seasonal and intermittent demand for relatively large quantities would require expensive regional and local storage facilities. Nevertheless, flyash employed properly in concrete increases workability, durability, compressive strength, and finish, all factors of economic value.

2.3 Concrete Products

Block, pipe, slabs and reinforced shapes constitute a worthwhile and continuing market, less subject to seasonal variation than poured-in-place concrete or asphalt paving fill. Flyash utilization in such products is steadily gaining acceptance.

2.4 Constituent in Portland Cement

This use of flyash in the manufacture of Portland cement, either as an additive or as a primary component is potentially of large volume. If flyash is added to the cement after firing the resulting material exhibits the same characteristics as do additions of ash to the mix at time of use. Flyash of normal composition employed as a raw material in the manufacture of cement has attracted some notice from experimentalists but with no clear outlook for improved characteristics in the cement. No work is reported on the use of high iron flyash specifically in the manufacture of cement.

2.5 Soil Stabilization

This use for flyash appears to offer very substantial market possibilities, at least for ash of normal composition. Lime-flyash stabilization has been developed considerably in recent years, and is the subject of a patent. The distribution of particle size in the aggregate, the moisture content, and the chemical composition, all bear on success possibilities in the use of ash for this purpose.

2.6 Light Weight Aggregate

The term "sintering" refers to the heating of fine aggregate to a temperature at which some of the periphery softens thus agglomerating the mass without melting it into a dense solid. Sintered flyash in concrete products behaves much as sintered clay or shale which are frequently so used. High iron ash would be heavier than desirable for this purpose, however.

2.7 Embankment and Fill

Fill projects offer an outlet for flyash of considerable volume on occasion, but an irregular one. Stock piling near the site of use would be necessary to supply this market. Construction practices normally require large volumes of fill in short time intervals, that is, peak demand for fill that would be normally greater than nearby production. The use of ash for land fill is usually less attractive than fill of other types since dust control of ash fill is often required together with other special costs. Land fill use is usually indistinguishable from dumping for which rental is normally an element of cost.

2.8 Other Outlets

"Siliconized" flyash for control of oil pollution on sea water was recently demonstrated in the U.K. Oil was released into a sea water lagoon which was thereupon sprayed with silicone treated flyash. The affinity of the siliconized flyash for the oil caused agglomeration and the mass subsequently sank. The hydrophobic nature and polarity of siliconized ash for bituminous materials has suggested other applications, for example, resistance to the flow of water through soils, filler in water resistant concrete, insulation for underground pipes, anti-caking filler for powders and bitumen. Admixture with concrete results in some loss of plasticity and an increased setting time, but concrete strength is not affected. Siliconized flyash is manufactured by treating air-entrained flyash with vaporized silanes or silicones. Such a method is efficient and production rates of several tons per hour have been obtained.

Cenospheres, the light weight ash particles that float on the surface of ponds, are being utilized as a coolant in some steel mills. Cenospheres are carbon dioxide and nitrogen filled microspheres of silicate glass ranging in size from

20 microns (about 700 mesh) to 200 microns (65 mesh). The mechanical strength, low density and flow characteristics allow them to be pumped as a liquid is pumped. They are excellent coolants for certain purposes.

Flyash is also being used to a limited degree in mine fire extinguishing, spontaneous combustion control, fire seals, mine subsidence, blasting grit, accoustical and thermal insulating blocks, and as a replacement for foundry core sand, filler for paints, plastics, putty, fertilizer, rubber, soap and paper. These smaller markets require the same specification control as larger markets with substantially less total revenue to be expected.

3. FLYASH APPLICATIONS IN DEVELOPMENT STAGE

Commercial production of high quality bricks manufactured of flyash, lighter and less expensive than clay materials, was known to be in the advanced planning stage by three large mineral companies and two electric utility companies.

Flyash has recently attracted the attention of water treatment specialists by reason of characteristics as follows:

a. Absorbent power for organic matter from water if unburned carbon is present.

b. Precipitation of inorganic phosphorous and neutralization of acidity.

c. Conditioning agent to improve filterability of waste sludges.

d. The good settling properties of flyash may be valuable in control of lake eutrophication (over-nourishment) such as that found in Lake Erie.

Flyash has been proposed in agricultural applications to correct plant growth deficiencies of boron, potassium, molybdenum and zinc. In some cases the ash increases crop yields, but further research appears necessary before large scale use is warranted.

4. PYRITIC ASH

The ash or cinder from iron sulfide (pyrite) roasting tends to the ferroso-ferric type of oxide (Fe_30_4) which is somewhat magnetic. The much higher temperatures and higher oxygen concentration of steam generators convert the pyrite in the fuel largely to the higher, non-magnetic oxide Fe_20_3. A process operated by Montecatini might be useful in separating an iron oxide concentrate from say the high iron (40 to 50%) ash of the CASE A System. (References, Volume One C and F, see also Appendix XII-C). The hot ash is treated with a reducing gas to convert the iron oxides to the magnetic form, followed by magnetic separation. If a concentrate of at least 60% iron content is won, the material may be salable (after pelletizing) for iron manufacture, sales value is of the order of 1¢ per pound of contained iron or say $12 per ton of concentrate.

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11. "Reducing Low Grade Iron Ores", Chemical Engineering Progress, November 1964.
12. "Fluidization Turns Pyrites Into High-Grade Iron Ore", Chemical Engineering, May 10, 1965.

13. "Commercial Chlorination of Iron Pyrite Cinder is a Success in Japan", Chemical Week, December 30, 1967.

14. "Kowa Seiko Process for Overall Utilization of Pyrites", Sulphur, March-April 1967.

15. "The Purification and Pelletization of Pyrites Cinders", Sulphur, July-August 1968.

16. Volume One, This Report, Ref (F) and (C).

17. "The Recovery Empire Built on Fool's Gold," Engineering and Mining Journal, December 1969.

COMPARATIVE ASH UTILIZATION, 1966 THROUGH 1969

	1966 Tons	1967 Tons	1968 Tons	1969* Tons
Fly Ash	17,123,144	18,409,854	19,813,747	22,304,513
Bottom Ash	8,065,583	9,131,453	7,259,212	8,042,017
Boiler Slag	-	-	2,554,569	3,020,282
TOTAL ASH PRODUCED	25,188,827	27,541,307	29,627,528	33,366,812
TOTAL ASH UTILIZED	3,050,669	3,794,714	5,194,016	5,306,764
% Fly Ash Utilized	7.9	8.2	9.6	9.4
% Bottom Ash Utilized	21.0	25.0	25.0	27.3
% Boiler Slag Utilized	-	-	57.8	33.7

*Preliminary Figures

Source: Second Ash Utilization Symposium, Pittsburgh, Pa.; March 10-11, 1970

ANNOTATED REFERENCES ON IRON RECOVERY FROM FLY ASH

1. Bartoszek, Boleslaw, et al, "Concentrates of Iron Oxides from Flue Dusts, "Polish Patent 48,027, March 1964. Describes the recovery of iron oxide from fly ash containing approximately 25 percent iron oxides. Iron oxides present in fly ash were reduced in a boiler with carbon monoxide to magnetite and separated magnetically. Concentrates contained 50 to 55 percent iron and the yield was 90 to 92 percent.
2. Gordon, S. A., "Ash As a Source of Iron Production," Nauch. Trudy Moskov. Gorn. Inst., (27), 137-43, 1959. Gasification of coal rendered iron in residue magnetic. (sic) Magnetic separation resulted in a concentrate containing 90 percent magnetite with over 92 percent iron recovery and a nonmagnetic fraction of more than 30 percent alumina which was of interest for aluminum production.
3. Guertler, William, M., "Alumina from Coal Ashes," U.S. Patent 1,873,642, August 1932. Describes a process for alumina recovery incorporating pretreatment by wet magnetic separation to remove iron followed by alumina extraction with hydrochloric acid.
4. Gegner, Hans, et al, "Reclaiming Metals and Nonmetals from Industrial Wastes," East German Patent 48,706, June 1966. Describes chlorination of dry lignite fly ash by treatment with chlorine and coke, phosgene or mixtures of these materials to reclaim germanium, iron, copper, boron and aluminum. Chlorine and hydrochloric acid formed during reclamation of metals after chlorination was recycled.

5. Joppa, Everett L., "Heavy Medium for Gravity Separation," U.S. Patent 3,021,282, February. 1962.

Describes use of magnetite obtained magnetically from fly ash for cleaning coal. Consumption of magnetite was 0.35 to 1.05 pounds per ton of feed, and the operating efficiency ranged from 98.5 to 99.4 percent.

6. Kogan, B. and Lileev, I., "Utilization of Ashes of Moscow Coal for the Recovery of Aluminum Oxide," Novosti Tekhniki, 10 (9, 10), 44-5, 1941 and Teplosilovoe Khoz., (2), 32-5, 1941.

Study showed that bituminous coal ash could be decomposed with concentrated sulfuric acid at 390 to 570° F. The resultant residue was leached, the solution was filtered and then mixed with concentrated sulfuric acid. The precipitate was dissolved in water, filtered through activated pyrolusite to free it of iron, concentrated and calcined. Method was only tested in the laboratory. Later study found that sintering with calcium carbonate and soda ash to be more expedient.

7. Kowalewski, Maciej and Mitka, Boleslaw, "Possibility of Producing (Iron Ore) Sinter with a Basicity of Two or More," Hutnik, 35, (4), 151-62, 1968, (Pol.).

Study made of sintering mixtures of ore and ore concentrates with limestone with fly ash and return sinter. Mixtures were prepared with basicities (ratio of lime to silica) of one through five. Increasing basicity of mixtures used in the steel works shortened the time of sintering and increased the reduction capacity and consumption of fly ash. Use of sinters with a basicity of three in blast furnaces eliminates limestone from the charge, reduces the consumption of coke by 10 to 15 percent and increases the production of pig iron by 10 to 15 percent.

8. Krejcirik, Libor and Zahradnik, Karel, "Recovery of Fe from Power Plant Ash," Chem. Prumysl, 16 (6), 326-9, 1966, (Czech.).
The results of experiments on fly ash from five Czechoslovak power plants burning both bituminous and lignite coal are described. High-quality iron concentrates, containing about 60 percent iron, were prepared by the refining separation of these fly ashes; however, sintering was required because of the fineness of the concentrates. Economic analysis showed the method to have high economic effectiveness.

9. Muller, Hans and Oversohl, Wilheim, "Aluminum Chloride and Iron Chloride," German Patent 802, 936, February 1951.
Describesprocess whereby fly ash and coal mining refuse is chlorinated in shaft or rotary furnaces at 110 to 1830° F to gasify the carbon, aluminum and iron present to form carbon monoxide for recycling and aluminum and iron chlorides which were recovered by condensation. A residue was obtained that was about 90 percent silica, which could be used as a catalyst carrier, filler or pigment.

10. Schubert, H., et al, "Flotation of the Electrofilter Ash of the Brown Coal Power Plants of Lower Lausitz," Freiberger Forschungsh, A 326, 45-47, 1964, (Ger.).
Describes flotation experiments made to determine feasibility of recovering iron from lignite fly ash. Flotation parameters and theory of flotation given.

11. Saeuberlich, K. and Richter, K.H., "Combustion Residues from Lower Lusatian Lignite as a Raw Material for Pig Iron Production," Freiberger Forschungsh, A 326, 7-16, 1964, (Ger.).

Study showed that high iron (20 to 30 percent) lignite combustion residues could be smelted in specially developed smelting devices. After successful laboratory testing, the process was carried out on a commercial scale without resorting to pilot plant work.

12. Theis, Bruno, "Heavy Media for Concentration of Coal," German Patent 950,721, October 1956.
Suggests use of silicate containing iron oxides obtained from fly ash by magnetic separation, as a medium in heavy-media cleaning of coal.

13. Wesolowski, Kornel and Ryczek, Michal, "Method of Preparing Fixed Heavy Metal Concentrates and Their Compounds from Hard and Brown Coals," Polish Patent 47,422, December 1963.
Describes recovery of reduced magnetic iron oxides by electromagnetic and/or gravity separation. The separated iron oxides also contained other heavy metal alloys which were further separated by differences in density.

XIII
CASE A SYSTEM

1. PROCESS DESCRIPTION (See Chemical System Flowsheet following page XIII-5)

1.1 Fuel Milling and Combustion

An HSC Fuel of the CASE A composition (See Table XI-1) containing 61.7% pyrite is milled to p.c. size and conveyed by preheated air to the down-firing burners of the Furnace, through the combustion and absorption zones and the preheaters, to cyclone collectors at the boiler exit. Combustion and steam generation proceed as described in Part XI. The steam product is of industrial quality at 500,000 lbs/hr as shown in the CASE A Flowsheet together with the distribution of ash, the flue gas composition and other data.

1.2 Startup of the Sulfuric Acid Train

A fuel fired Start-Up Furnace provides the heat necessary to bring the acid plant to temperature before commencing operation. One startup system is provided but all other SO_2 recovery equipment except the tail-gas treating section, is arranged in two parallel trains.

1.3 Purification of the 6% SO_2 Flue Gas

The flue gas at 500° F is first cooled and saturated in the Scrubbing Tower to adjust its moisture content to the production of 98% H_2SO_4. Weak acid liquor is circulated through the Cooler and over the scrubbing tower. Water is added to the scrubbing liquor as required to maintain it at the desired acid concentration, and the system is continuously purged to remove the accumulating solids.

The SO_2 absorbed from the gas by the purged liquor is stripped with air and returned to the gas stream leaving the scrubbing tower. The Stripper is a partially packed tower equipped with a small air fan. The last traces of dust and sulfuric acid mist are then removed from the cooled gas in an Electrostatic Mist Precipitator.

Cleaned and cooled gas flows to the Drying Tower where it is dried by 93% acid which is circulated over the drying tower by a vertical submerged pump located in the Pump Tank. The heat generated by the absorption of water in the circulating acid is removed in cast iron Acid Cooler sections, which are cooled with water.

A second Stripper returns SO_2 from the drying tower acid solution to the drying tower gas entrance. The SO_2 Blower maintains the purification equipment and drying tower under suction and pushes the gas through the converting and absorbing equipment.

1.4 SO_2 Conversion

The gas leaving the SO_2 Blower passes through Entrance Heat Exchangers, where the gas is heated to the optimum temperature for conversion of SO_2 to SO_3 in the first vanadium catalyst bed of the four-stage Converter. Conversion of SO_2 to SO_3 is only partially complete in the first catalyst bed and the gas must be passed successively through the additional beds, with intermediate cooling, to reach the optimum conversion of SO_2 to SO_3. Cooling between the first and second catalyst beds is provided by the Converter Heat Exchanger. Between the second and third, and third and fourth beds it is accomplished by means of air cooling coils located between the catalyst beds. A small Air Fan provides cooling air for this service.

Almost all of the SO_2 gas, now converted to SO_3, passes back through the entrance heat exchangers where it is cooled to a suitable temperature for absorption in 98% acid. These heat exchangers simultaneously heat the SO_2 gas before it enters the converter.

1.5 SO_3 Absorption

The SO_3 gas (at about 350° F) goes to the 98% Absorption Tower, where its SO_3 content is absorbed in the 98% sulfuric acid circulating over the tower. Water absorbed from the saturated SO_2 gas and water added to the system maintain the balance of acid strength desired.

The heat rise in the acid (resulting from the addition of water, heat of absorption of SO_3, and sensible heat in the incoming gas) is removed from the acid as it flows by gravity through the 98% Acid Coolers to the 98% Acid Pump Tank. A vertical submerged pump recirculates the 98% acid over the absorption tower and also delivers part of it to the 93% acid system. Means are provided to discharge either 93% or 98% acid continuously to storage. Acid transfer lines between the drying and absorption systems provide the means of keeping both acids at the best concentration for drying and absorption.

1.6 Tail Gas Clean-Up

The tail gas leaving the absorption tower still contains about 1,000 ppm of unconverted SO_2 plus some acid mist and SO_3, the bulk of which is removed before discharging the tail gas to atmosphere. Sulfur dioxide, SO_3 and acid mist are absorbed in a single-stage venturi Scrubber. The scrubbing liquid is a slurry containing hydrated lime, calcium sulfite and calcium sulfate. The reactions in the scrubber are as follows:

$$\begin{array}{lllll}
Ca(OH)_2 & + SO_2 & + H_2O & \longrightarrow & CaSO_3 . 2H_2O \\
Ca(OH)_2 & + SO_3 & + H_2O & \longrightarrow & CaSO_3 . 2H_2O \\
Ca(OH)_2 & + H_2SO_4 & & \longrightarrow & CaSO_3 . 2H_2O \\
CaSO_3 . 2H_2O & + 1/2O_2 & & \longrightarrow & CaSO_3 . 2H_2O
\end{array}$$

Following absorption the slurry is held in a Delay Tank to precipitate any calcium sulfate in supersaturated solution. This is done to avoid the scaling-out of this salt in the lines and the scrubber.

A bleed stream is drawn from the scrubber system to separate the sulfur salts equivalent to the sulfur gases being absorbed. Sulfite, sulfate and some alkali are settled out in the Thickener.

The underflow is centrifuged and the wet solids are conveyed to a storage hopper or railroad car for disposal. The mother liquor is sent back to the scrubber along with the overflow from the thickener. Lime and make-up water are added to the scrubber system via a slaking tank:

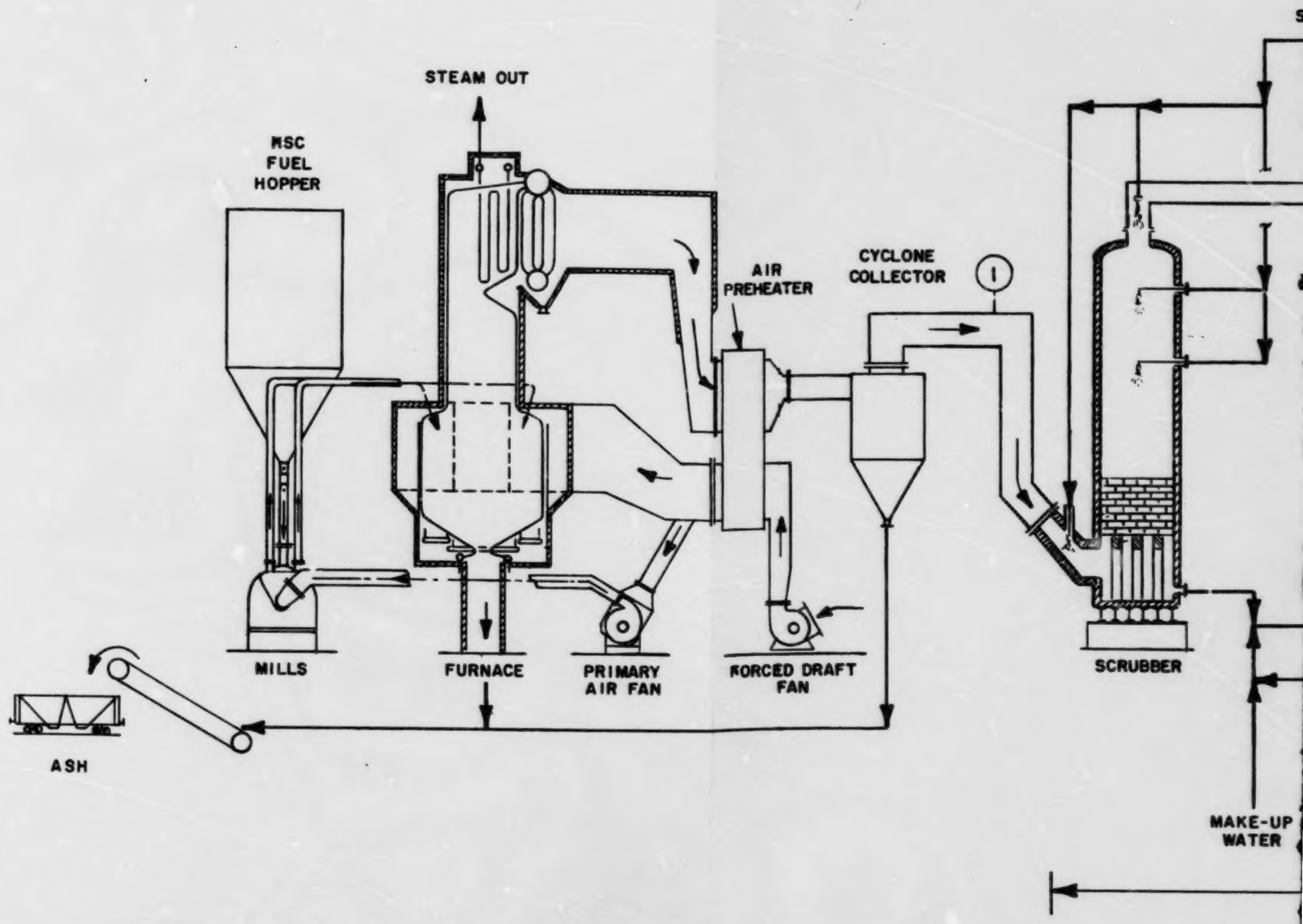
$$CaO + H_2O \longrightarrow Ca(OH)_2$$

The purged particulates from the flue gas scrubbers at the front end of the plant slurried in the weak acid solution are also introduced to the thickener, where sufficient excess alkalinity is maintained to neutralize the acid and precipitate calcium sulfate. The non-pyritic ash, iron oxide and calcium sulfate are also separated in the Centrifuge and discharged with the calcium sulfate produced in the scrubbing system. The tail gas, containing 100 ppm or less SO_2, is discharged to atmosphere.

1.7 Product Sulfuric Acid is of Commercial Grade - 93 to 98% concentration as desired.

1.8 Turndown ratio of the CASE A sulfuric acid system is about 4 to 1 since either train can be operated independently down to about 50% of capacity. The concentration of SO_2 in the flue gas should be maintained at 6% if possible. Lower concentrations will result in diminished efficiency.

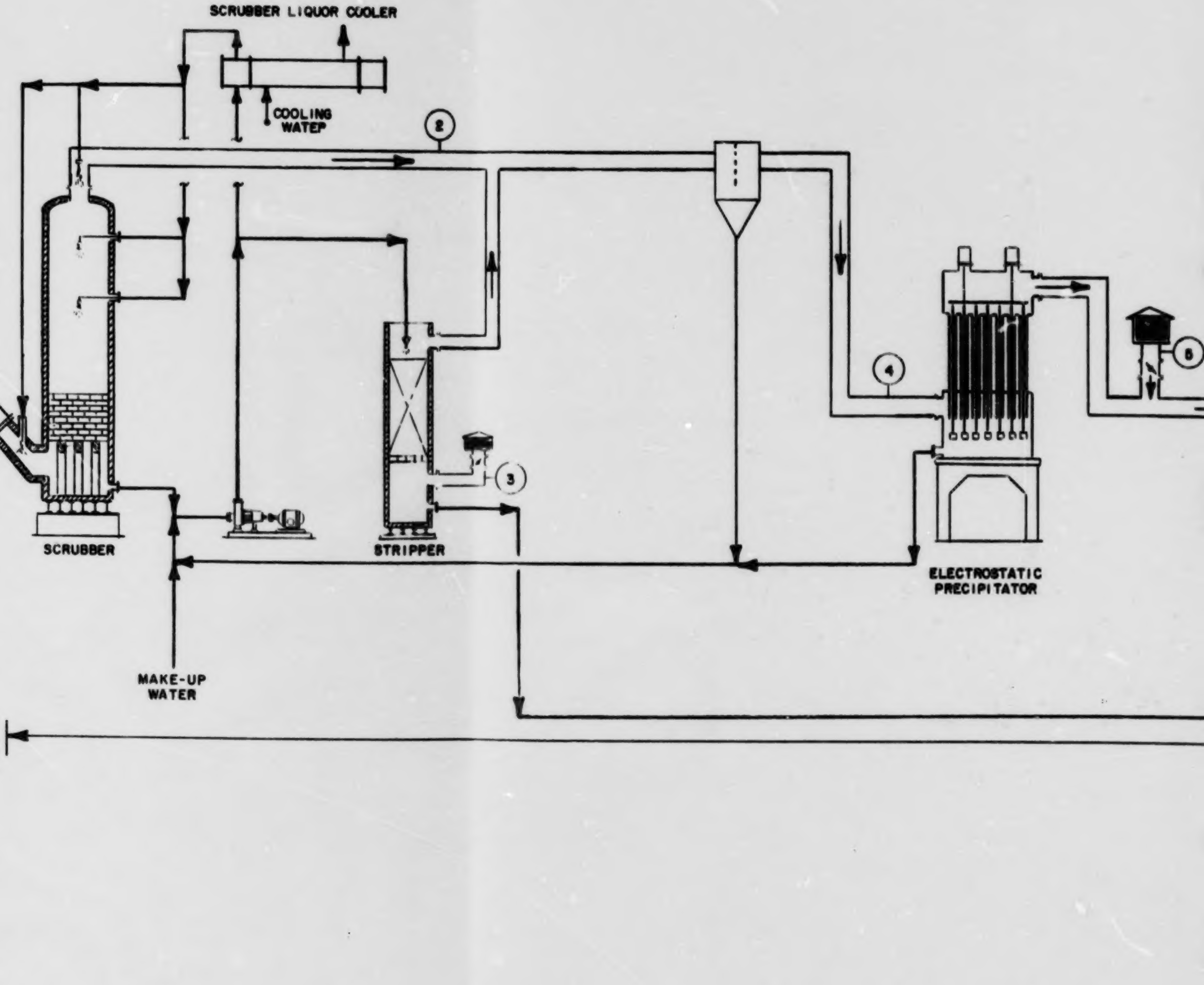
COMBUSTION


STEAM OUT
HSC FUEL HOPPER
AIR PREHEATER
CYCLONE COLLECTOR
①
MILLS
FURNACE
PRIMARY AIR FAN
FORCED DRAFT FAN
SCRUBBER
ASH
MAKE-UP WATER

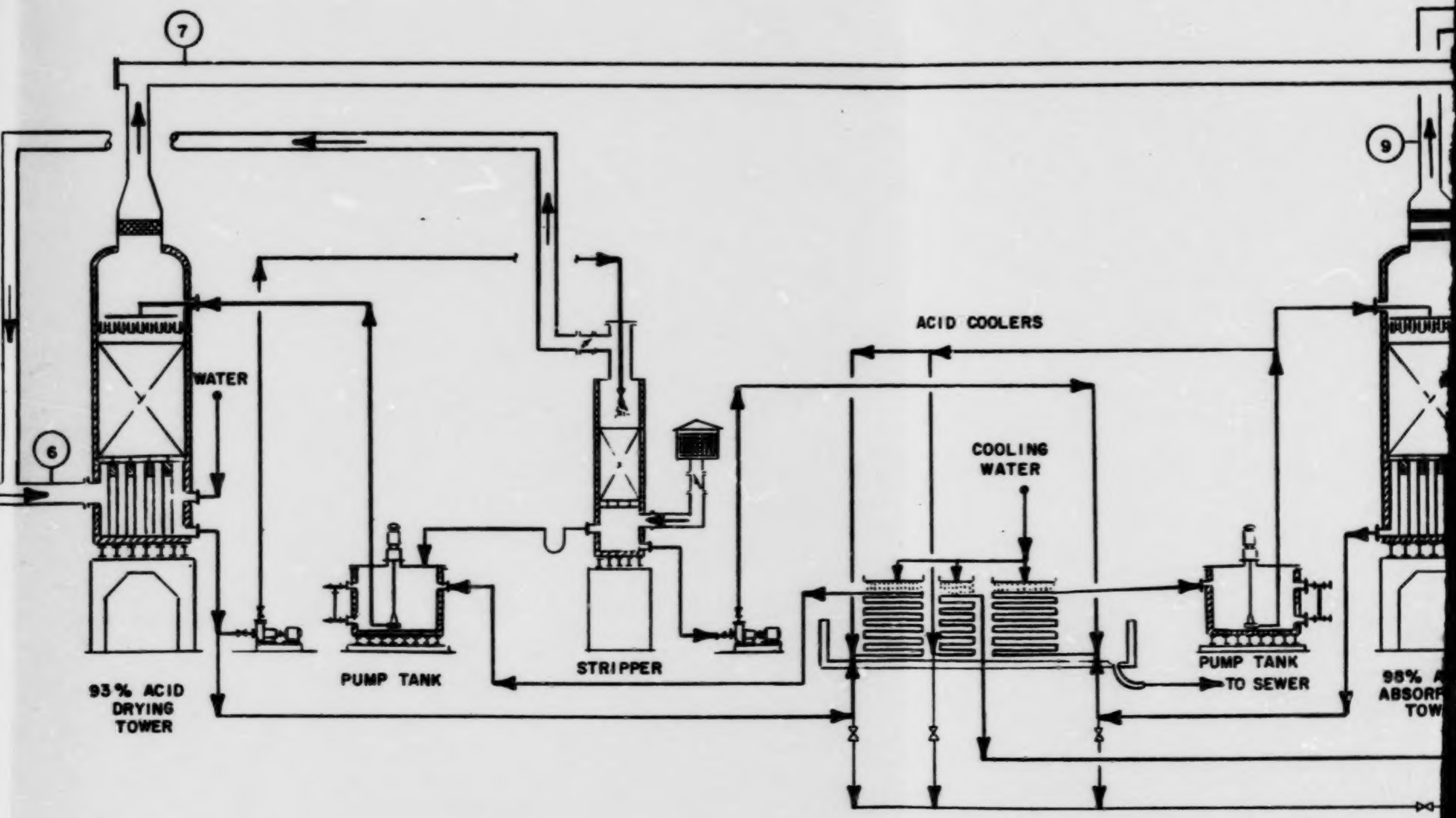
HSC FUEL	
TOTAL FUEL FLOW	160,000 LBS/HR
IRON PYRITE	98,600 "
COAL COMBUSTIBLES	29,400 "
NON-PYRITIC ASH	32,000 "
HIGHER HEATING VALUE	4,424 BTU/LB
ENERGY INPUT	700 x 10 BTU/HR

STEAM SECTION	
STEAM FLOW	500,000 LBS/HR
STEAM PRESSURE	900 PSIG
STEAM TEMPERATURE	825° F
NET HEAT OUTPUT	569 x 10 BTU/HR
REHEAT	NONE
FEED WATER	300°F
FLUE GAS EXIT-AIR HEATER	500°F

ASH DISTRIBUTION	
TOTAL ASH	97,600 LBS/HR
FURNACE BOTTOM	19,500
CYCLONE	62,500
WET SCRUBBER	15,600
% IRON IN ASH	47


SCRUBBER LIQUOR COOLER
COOLING WATER
2
SCRUBBER
STRIPPER
3
4
5
ELECTROSTATIC PRECIPITATOR
MAKE-UP WATER

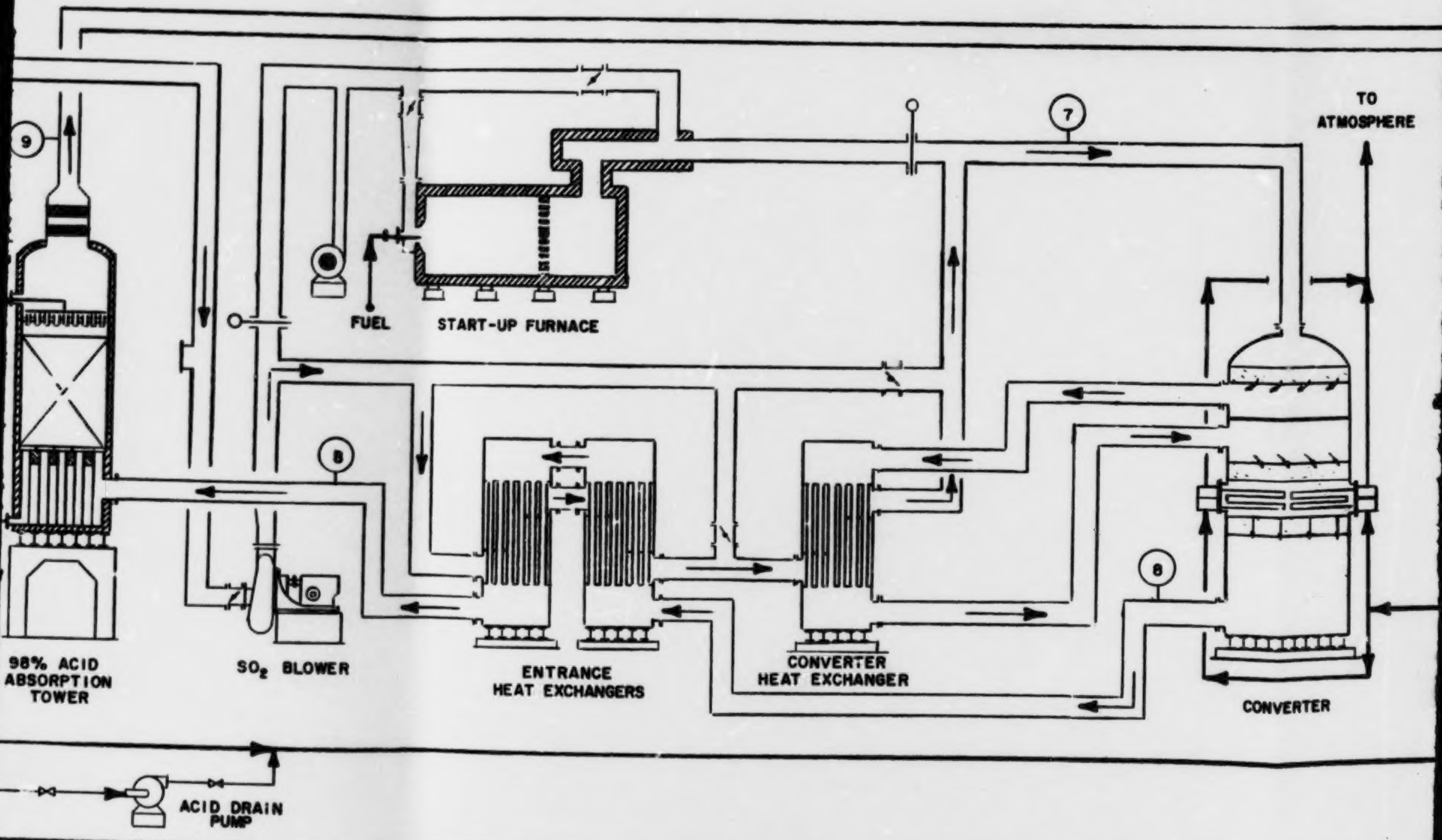
SO_2 RECOVERY


7
9
6
WATER
ACID COOLERS
COOLING WATER
93% ACID DRYING TOWER
PUMP TANK
STRIPPER
PUMP TANK
TO SEWER
98% A
ABSORP
TOW

TWO TRAINS

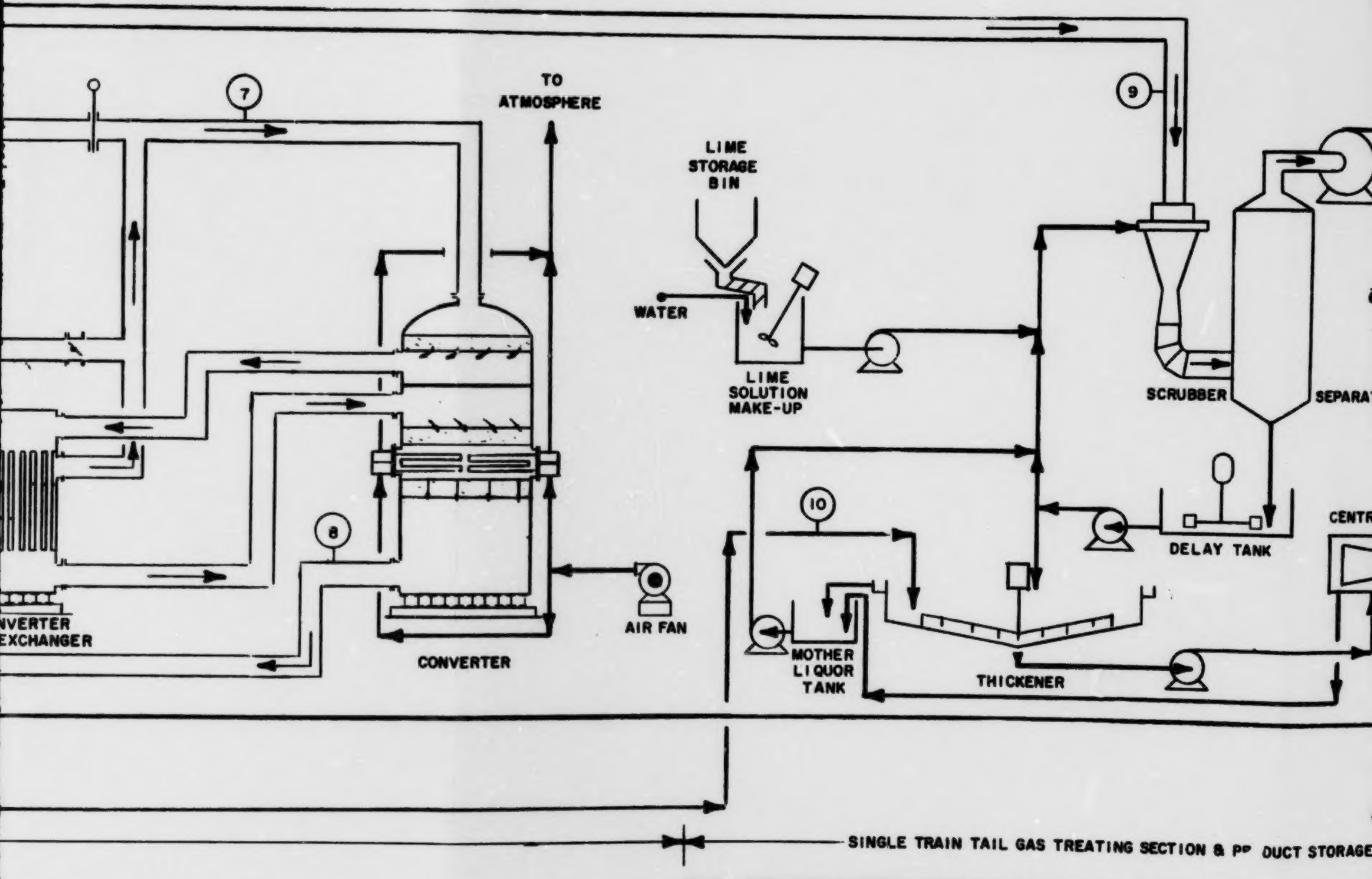
	SCRUBBING-ABSORPTION SECTION													
DESIGNATION	①		②		③		④		⑤		⑥		⑦	
	FLUE GAS		SCRUBBER EXIT GAS		STRIPPER AIR		PRECIPITATOR ENTRANCE GAS		MAKE - UP AIR		DRYING TOWER ENTRANCE GAS		DRIED GAS	
COMPONENT	VOL.%	LB. MOLS/HR	VOL.%	LB. MOLS/HR	VOL.%	LB. MOLS/HR	VOL.%	LB. MOLS/HR	VOL.%	LB. MOLS/HR	VOL.%	LB. MOLS/HR	VOL.%	LB. MOLS/HR
SO_2	5.7	1,597	5.6	1,597			5.5	1,597			4.7	1,597	5.0	1,597
SO_3	0.2	56	0.2	56			0.2	56						
O_2	4.1	1,149	4.0	1,149	17.9	40	4.1	1,189	20.2	1,047	6.7	2,236	7.1	2,236
CO_2	8.3	2,325	8.2	2,325			8.1	2,325			6.8	2,325	7.2	2,325
N_2	77.7	21,769	76.3	21,769	76.7	171	76.4	21,940	76.0	3,939	76.4	25,879	80.7	25,879
H_2O	4.0	1,121	5.7	1,621	5.4	12	5.7	1,633	3.8	197	5.4	1,830		
TOTAL	100.0	28,017	100.0	28,517	100.0	223	100.0	28,740	100.0	5,183	100.0	33,867	100.0	32,037
SCFM (60°F, 14.7 PSIA)	177,180		180,342		1,410		181,752		32,777		214,175		202,802	
DUST LBS/HR	15,600													

OVERY



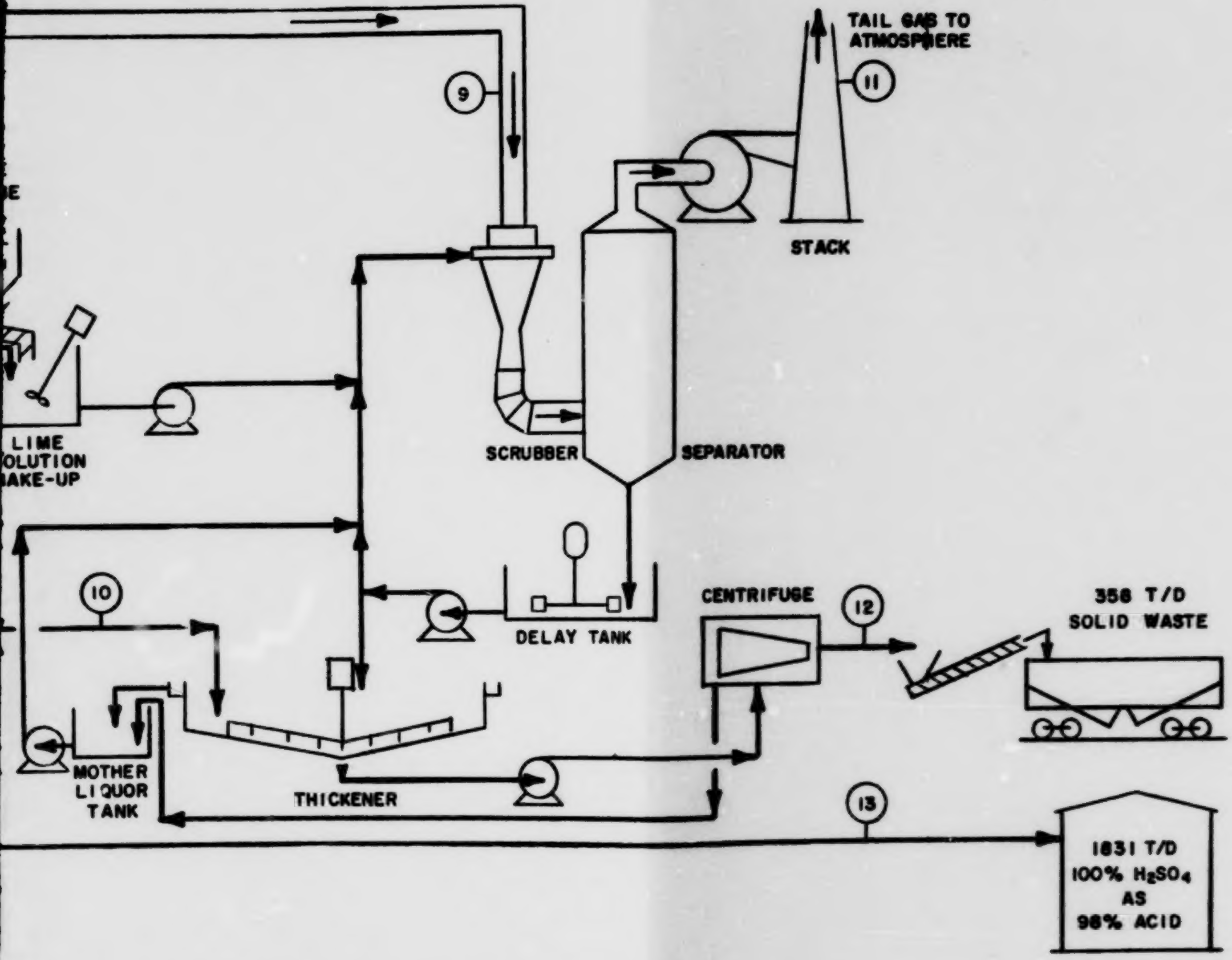
9
7
TO
ATMOSPHERE
FUEL
START-UP FURNACE
8
8
98% ACID
ABSORPTION
TOWER
SO_2 BLOWER
ENTRANCE
HEAT EXCHANGERS
CONVERTER
HEAT EXCHANGER
CONVERTER
ACID DRAIN
PUMP

	⑧		⑨		⑩	
AS	CONVERTER EXIT GAS		ABSORBER TAIL GAS		STRIPPER BOTTOMS	
.B. S/HR	VOL.%	LB. MOLS/HR	VOL.%	LB. MOLS/HR	VOL.%	LB. MOLS/HR
597	0.1	20	0.1	20		
	5.0	1,557			0.8	74
236	4.7	1,457	5.1	1,457		
325	7.4	2,325	7.7	2,325		
879	82.8	25,879	87.1	25,879		
					99.2	10,484
					100,0	10,558
037	100.0	31,238	100.0	29,681		
	197,549		187,703			
					15,600	


7
TO ATMOSPHERE
9
LIME STORAGE BIN
WATER
LIME SOLUTION MAKE-UP
SCRUBBER
SEPARAT
NVERTER EXCHANGER
CONVERTER
AIR FAN
8
10
DELAY TANK
CENTR
MOTHER LIQUOR TANK
THICKENER
SINGLE TRAIN TAIL GAS TREATING SECTION & PRODUCT STORAGE

DESIGNATION / COMPONENT	⑪ SCRUBBER TAIL GAS		⑫ SOLID WASTE	⑬ PRODUCT ACID
	VOL. %	LB. MOLS/HR	LBS/HR	LBS/HR
SO_2	.01	4		
SO_3	NIL			
O_2	4.8	1,487		
CO_2	7.5	2,325		
NOx	NIL			
N_2	84.4	25,879		
H_2O	3.2	975		3,114
TOTAL-GASES	100.0	30,640		
H_2SO_4				152,586
SCFM (60°F, 14.7 PSIA)	193,860			
DUST			15,600	
CaSO -2H O			12,730	
TOTAL-LIQUID & SOLID			29,821	155,700

CASE A


TAIL GAS TO ATMOSPHERE
11
STACK
9
E
SCRUBBER
SEPARATOR
LIME
OLUTION
AKE-UP
10
DELAY TANK
CENTRIFUGE
12
358 T/D
SOLID WASTE
MOTHER
LIQUOR
TANK
THICKENER
13
1831 T/D
100% H_2SO_4
AS
98% ACID

SINGLE TRAIN TAIL GAS TREATING SECTION & P^P OUCT STORAGE

DESIGNATION / MPONENT	⑪ SCRUBBER TAIL GAS		⑫ SOLID WASTE	⑬ PRODUCT ACID
	VOL. %	LB. MOLS/HR	LBS/HR	LBS/HR
	.01	4		
	NIL			
	4.8	1,487		
	7.5	2,325		
	NIL			
	34.4	25,879		
	3.2	975		3,114
L-GASES	100.0	30,640		
4				152,586
(60°F, 14.7 PSIA)	193,560			
			15,600	
-2H O			12,730	
L-LIQUID & SOLID			29,821	155,700

HIGH SULFUR COMBUSTOR STUDY

FLOW SHEET AND QUANTITIES

———o———

ENERGY PRODUCT

STEAM: 500,000 LBS/HR

@ 825°F 900 PSIG

CHEMICAL PRODUCT-COMMERCIAL

GRADE 98% SULFURIC ACID

1831 T/D ON 100% BASIS

2. SUMMARY OF CAPITAL COST

CASE A	Erected Cost Basis
Combustor System (See Part XI)	$5, 113, 000
Two train contact acid plant including storage and loading	10, 700, 000
Tail gas cleaning and stack	600, 000
Total less land	$19, 413, 000 .

Fixed and working capital costs are also discussed in Volume One, Part VIII.

XIV
CASE B SYSTEM

1. PROCESS DESCRIPTION (See CASE B data in Table XIV-1)

1.1 Fuel Milling and Combustion

An HSC Fuel of the CASE B composition (See Table XI-1) containing 33.8% iron pyrite is milled to p.c. size and conveyed by preheated air to the burners of a 500,000 lbs/hr industrial steam boiler of a special design for integration with the Cat-Ox SO_2 recovery equipment specified for CASE B.

1.2 Flue Gas Cleaning (See Cat-Ox Flowsheet following page XIV-11)

Combustion gas containing about 2% SO_2 and all fly ash are conducted out of the boiler at 805° F directly into Electrostatic Precipitators by which particulate matter is removed virtually completely from the gas stream into hoppers that are periodically dumped to an ash settling pond.

1.3 Conversion of SO_2 to SO_3

The hot, clean gas passes through the Converter beds where SO_2 is oxidized on Cat-Ox A* catalyst to SO_3. A

*** Trademark of Monsanto Enviro-Chem Systems, Inc.**

temperature rise of 75° F and conversion of 93% is expected with this gas strength.

There is a gradual buildup of fly ash in the converter and thus a gradual increase in pressure drop across the unit over a period of time. While fly ash buildup does not much affect conversion efficiency, a need for catalyst cleaning four times a year is anticipated. Equipment is provided to convey mechanically, clean and return the catalyst to the converter with minor loss of material and with no loss of activity. Total downtime for this cleaning operation including catalyst cool-off, cleaning, and heat-up is estimated at two days for each converter module. The procedure requires two maintenance men each shift for three shifts to operate the catalyst handling equipment. Experience has shown that approximately 2.5% of the catalyst by volume must be added with each cleaning operation to replace losses from screening and mechanical handling.

1.4 Heat Recovery

Gas leaving the converter passes to an Air Heater where the heat in the gas is absorbed and returned to the boiler cycle. The converter exit gas is cooled to 450° F by heating the boiler combustion air to 370° F in the exchange.

The combustion gas air heater is supplemented by a Steam Air Heater which uses extraction steam from the turbine as its heat source, and a Fluid Air Heater which utilized heat extracted from hot recirculating Product Acid. Air at ambient temperature is heated to about 300° F by these two supplementary heat exchangers before it passes through the main air heater. The Forced Draft Fans which move the combustion air through this heat absorption equipment are an integral part of the Cat-Ox system. The Induced Draft Fans which move the flue gas through the Cat-Ox system are located downstream from the air heater.

1.5 Sulfuric Acid Collection

Following heat recovery and cooling to 450° F the flue gas passes to Absorbing Tower in which the gas is brought into contact with a stream of cool sulfuric acid which condenses the newly synthesized sulfuric acid vapor in the gas stream. The heated circulating acid drains to the bottom of the tower and thence to external shell and tube heat exchangers in which it is cooled and recycled to the tower by Circulating Pumps. An acid level controller in the tower diverts a portion of the circulating acid through the Product Acid Cooler to the Storage Tank. About half of the acid heat is ultimately transferred to the combustion air as described above. The acid heat is first transferred to circulating water, the circulating water in turn preheats the air to the main air heater. The remainder of the acid is transferred directly to cooling water. The Acid Circulation Coolers are constructed of graphite tubes and steel shells. The fluid/air heaters are steel.

Very fine mist particles of sulfuric acid are formed in the gas as it is cooled in the absorbing tower. These mist particles are removed along with some entrained droplets of circulating acid in the tower by the Mist Eliminator. This unit is located in the upper section of the absorbing tower and is made of fiber-packed elements. The sulfuric acid collected by the mist eliminators is added to the circulating acid stream.

The acid produced in this system contains a small quantity of settleable solids (less than 0.1%) which is essentially fly ash. Entrained acid droplets from the absorbing section of the tower can carry these solids onto the surfaces of mist eliminator elements. With time the gradual buildup may result in increased draft loss across these elements. To overcome this and insure clean element performance, an internal water works system has been provided by which the elements may be cleaned periodically. All elements are equipped with wash piping so that all can be flushed when required and as the operators' duties permit.

1.6 Intermediate Storage

Cooled Cat-Ox acid at 60° Baume (77.7% H_2SO_4) is collected in vertical steel Storage Tanks.

1.7 Concentration of Cat-Ox Acid to 93-98% Commercial Grade, Storage and Loading

In order to apply comparable sales value criteria to the sulfuric acid product of the Cat-Ox process and the standard contact process the capital cost and operating cost estimates of XIV-4 and VII-2 reflect the addition of drum concentrating equipment to the Cat-Ox system in order to upgrade the Cat-Ox product to 93-98% Commercial Grade Sulfuric Acid.

1.8 Tail-Gas Treating

The Cat-Ox system adapted to CASE B is "designed to achieve 93% conversion, and SO_2 content of the gas following treatment will be 1,400 ppm." The bulk of this is removed before discharging to atmosphere by the addition of treating equipment similar in design and operation to that described in XIII-1.6. A single-stage venturi scrubber circulates a slurry of calcium hydroxide, calcium sulfite and calcium sulfate. The sulfur salts are settled in a thickner, the overflow is returned to the scrubbing cycle, and the underflow is centrifuged. The solids are dumped.

TABLE XIV-1

CASE B DATA

	Clean Coal	HSC Fuel, Dry	HSC Fuel As Fired
FeS_2, %		34.6	29.4
Organic S, %	1		
Total S, %	1		
Coal Combustibles, %		45.4	38.6
Non-Pyritic Ash, %		20.0	17.0
Moisture, %		--	15.0
Btu/Lb		7395	6286
FeS_2, Lb/Hr			35078
Coal, Lb/Hr			46055
N-P Ash, Lb/Hr			20283
Moisture, Lb/Hr			17897
Total, Lb/Hr			119313
Sulfur/Coal Ratio			0.4
Input, MM Btu/Hr			750
M Tons/Year			477

	To Cat-Ox, % Volume	
	Dry	Wet
SO_2	2.03	1.92
SO_3	0.08	0.08
O_2	4.20	3.97
CO_2	14.01	13.25
N_2	79.68	75.36
H_2O	--	5.42

Temp., °F	805
M Lb/Hr	883
MACFM	445
MSCFM	173
Fly Ash Lb/Hr	34935
% Fe	37.5

R. E. Z.
4/30/70
Rev. 7/18/70

2. EQUIPMENT LIST

Major pieces of equipment included in the Cat-Ox system are listed below.

ITEM	NUMBER	DESCRIPTION
Precipitators	1	High temperature, high efficiency, electrostatic precipitator.
Converters	2	Cat-Ox converters for supporting Cat-Ox A catalyst as a fixed bed in a shell. Individual units operate in parallel but independently of each other so that any unit can be cleaned without affecting the performance of the other units. Sufficient Cat-Ox A catalyst is supplied to charge all units.
Air Heater	1	Gas to air heat exchanger.
Forced Draft Fan	1	Centrifugal fan with direct connected 1, 500 HP, 1, 200 RPM motor drive.
Fluid/Air Heater	1	Finned tube liquid to air heat exchanger.
Steam/Air Heater	1	Finned tube steam coil air heater.
Induced Draft Fan	1	Centrifugal fan with direct connected 3, 500 HP, 1, 200 RPM motor drive.

ITEM	NUMBER	DESCRIPTION
Absorbing Tower - Mist Eliminator	1	Vertical, cylindrical, bricklined, packed tower. The units are designed for the Cat-Ox system and each is equipped with an acid distribution system, a Cat-Ox mist eliminator and a mist eliminator wash system.
Acid Circulating Pumps	3	Centrifugal pumps with direct connected 60 HP motor drives. The units operate in parallel but independently of each other. Two units are active and one is an installed spare.
Acid Circulation Coolers	6	Shell and tube liquid to liquid heat exchangers. The units operate in parallel, independently of each other. Two are installed spares.
Product Acid Coolers	2	Shell and tube liquid to liquid heat exchanger.
Product Acid Storage Tanks	8	Vertical, cylindrical, covered tanks 60 feet diameter, 30 feet high.
Acid Loading Pumps	2	Centrifugal pumps with motor drives are provided to load acid for shipment.
Catalyst Separators Catalyst Storage Bins Catalyst Conveyors Catalyst Elevators	1	Complete system of valves, conveyors and screens provided to unload, and clean dirty catalyst and reload.
Fly Ash System Exhaust Water Pump	1	Pneumatic conveying system for collecting fly ash from precipitator hoppers and transporting to battery limits. Gates provided between each hopper and pneumatic conveying line.

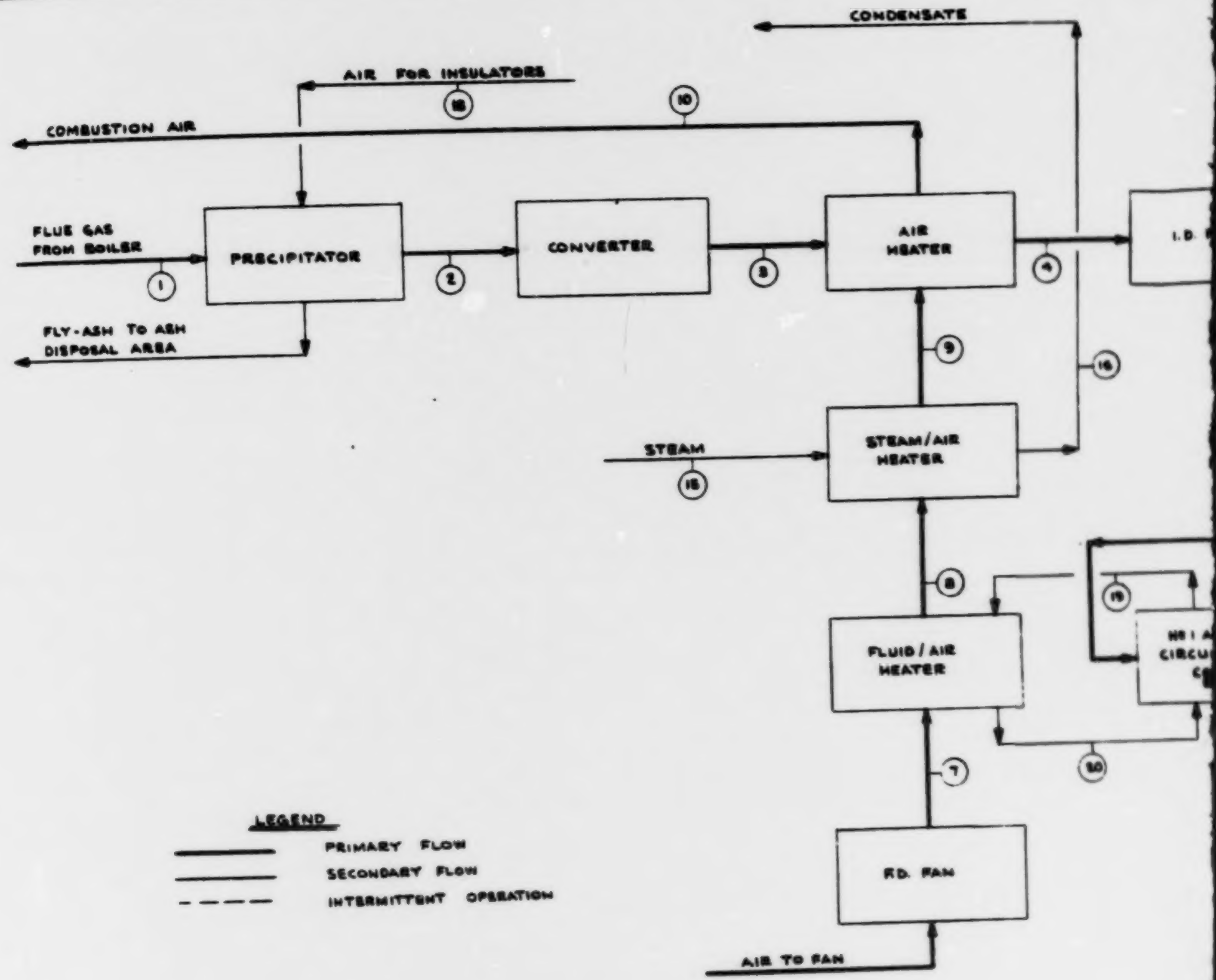
All necessary connecting ductwork, piping, control and monitoring instrumentation, electrical work, electrical pipe heating, insulation, foundations, supports, access structures, acid loading docks, safety showers and neutralization pit are provided.

3. PROCESS AND UTILITY REQUIREMENTS

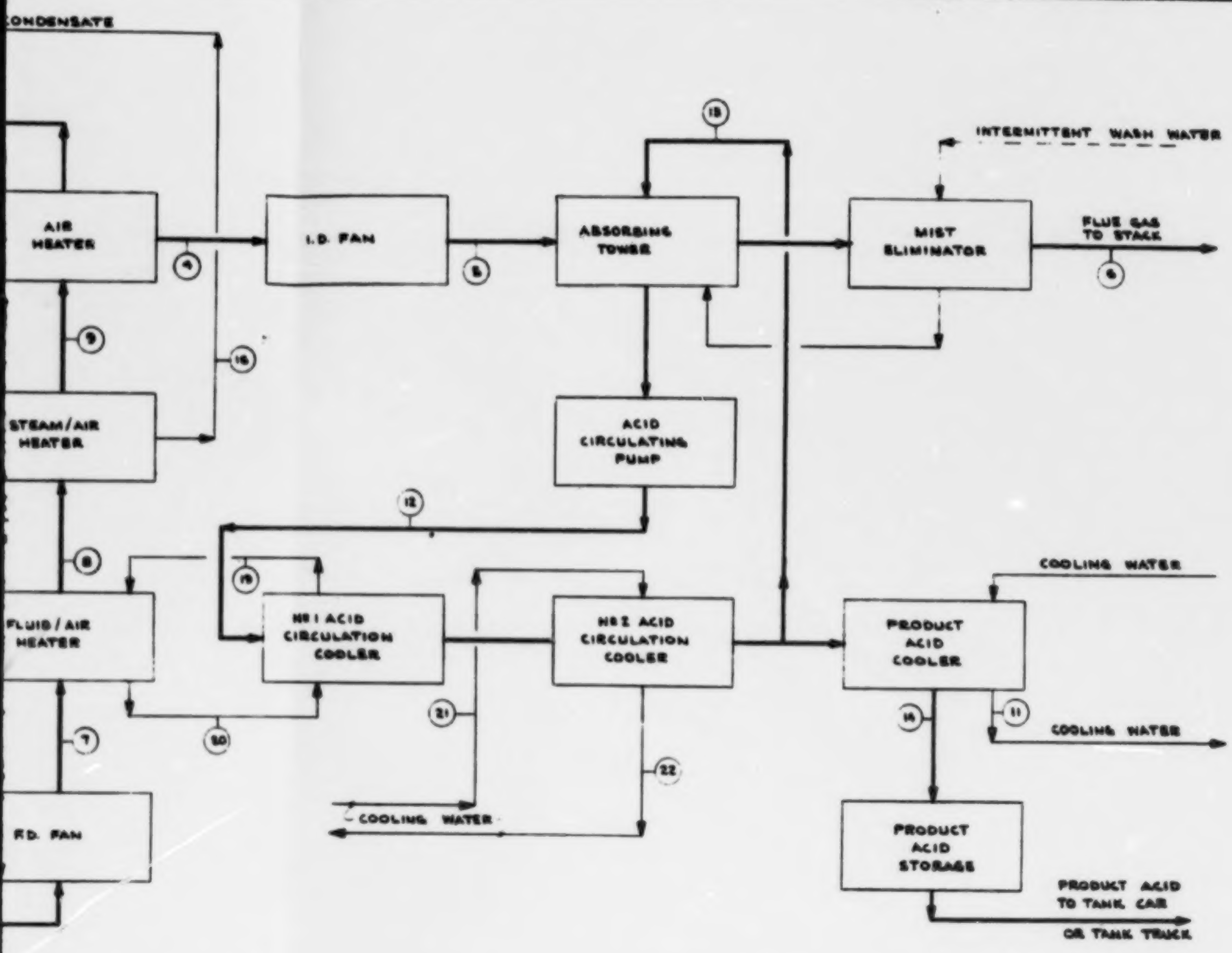
Plant design assumes that process and utility streams are supplied to the Cat-Ox system battery limits. All quantities and conditions are for full load operation.

		INLET	OUTLET
3. 1	Combustion Air		
	Temperature, F	80	730
	Pressure, in. of water	---	20. 0
	Quantity, Lb/Hr	---	807, 000
3. 2	Steam* and Condensate		
	Pressure, PSIA	350	315
	Quantity, Lb/Hr	32, 600	32, 600
	Enthalpy, Btu/Lb	1, 204	400
3. 3	Cooling Water		
	Temperature, F	90	120
	Quantity, GPM	5, 340	5, 340
3. 4	Potable Water (for Safety Showers)		
	Pressure, PSIG	75	---
	Quantity, GPM	50	---
3. 5	Electric Power		
	3 Phase, 60 Cycle, 400, 2, 300 or 4, 600 Volt,		
	Connected HP	6, 225	---
	Operating Kw	3, 500	---
3. 6	Fly Ash		
	Quantity, Lb/Hr	---	35, 000
3. 7	Sulfuric Acid		
	Temperature, F	---	100
	Strength	---	60° Baumé
	Quantity, Lb/Hr	---	68, 000

* High pressure extraction steam from intermediate pressure turbine.


CONDENSATE
AIR FOR INSULATORS
18
10
COMBUSTION AIR
FLUE GAS FROM BOILER
1
PRECIPITATOR
2
CONVERTER
3
AIR HEATER
4
I.D.
FLY-ASH TO ASH DISPOSAL AREA
9
16
STEAM
15
STEAM/AIR HEATER
8
19
FLUID/AIR HEATER
CIRCU
20
7
LEGEND
PRIMARY FLOW
SECONDARY FLOW
INTERMITTENT OPERATION
F.D. FAN
AIR TO FAN

STREAM Nº	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
STREAM	FLUE GAS	FLUE GAS TO CONV.	FLUE GAS TO AIR HTR.	FLUE GAS TO I.D. FAN	FLUE GAS TO ABSORB. TOWER	FLUE GAS TO STACK	AIR TO FLUID/ AIR HTR.	AIR TO STEAM/ AIR HTR.	AIR TO AIR HTR.	COMBUST. AIR	COOLING WATER OUT	ACID TO ACID/CIRC COOLERS	ACID TO ABSORB TOWER	PRODUCT ACID	STEAM TO STEAM/ AIR. HTR.	CON SAT FEE


CONDENSATE
AIR HEATER
I.D. FAN
ABSORBING TOWER
MIST ELIMINATOR
INTERMITTENT WASH WATER
FLUE GAS TO STACK
STEAM/AIR HEATER
ACID CIRCULATING PUMP
FLUID/AIR HEATER
NO1 ACID CIRCULATION COOLER
NO2 ACID CIRCULATION COOLER
PRODUCT ACID COOLER
COOLING WATER
COOLING WATER
COOLING WATER
F.D. FAN
PRODUCT ACID STORAGE
PRODUCT ACID TO TANK CAR OR TANK TRUCK
4
5
6
7
8
9
11
12
13
14
16
19
20
21
22

12	13	14	15	16	17	18	19	20	21	22
ACID TO ACID/CIRC COOLERS	ACID TO ABSORB TOWER	PRODUCT ACID	STEAM TO STEAM/ AIR, HTR.	CONDEN-SATE TO FEED WATER HTR.	FUEL TO BOILER	AIR FOR INSUL-ATORS	FLUID TO FLUID/ AIR HTR.	FLUID TO ACID CIRC. COOLER	COOLING WATER IN	COOLING WATER OUT

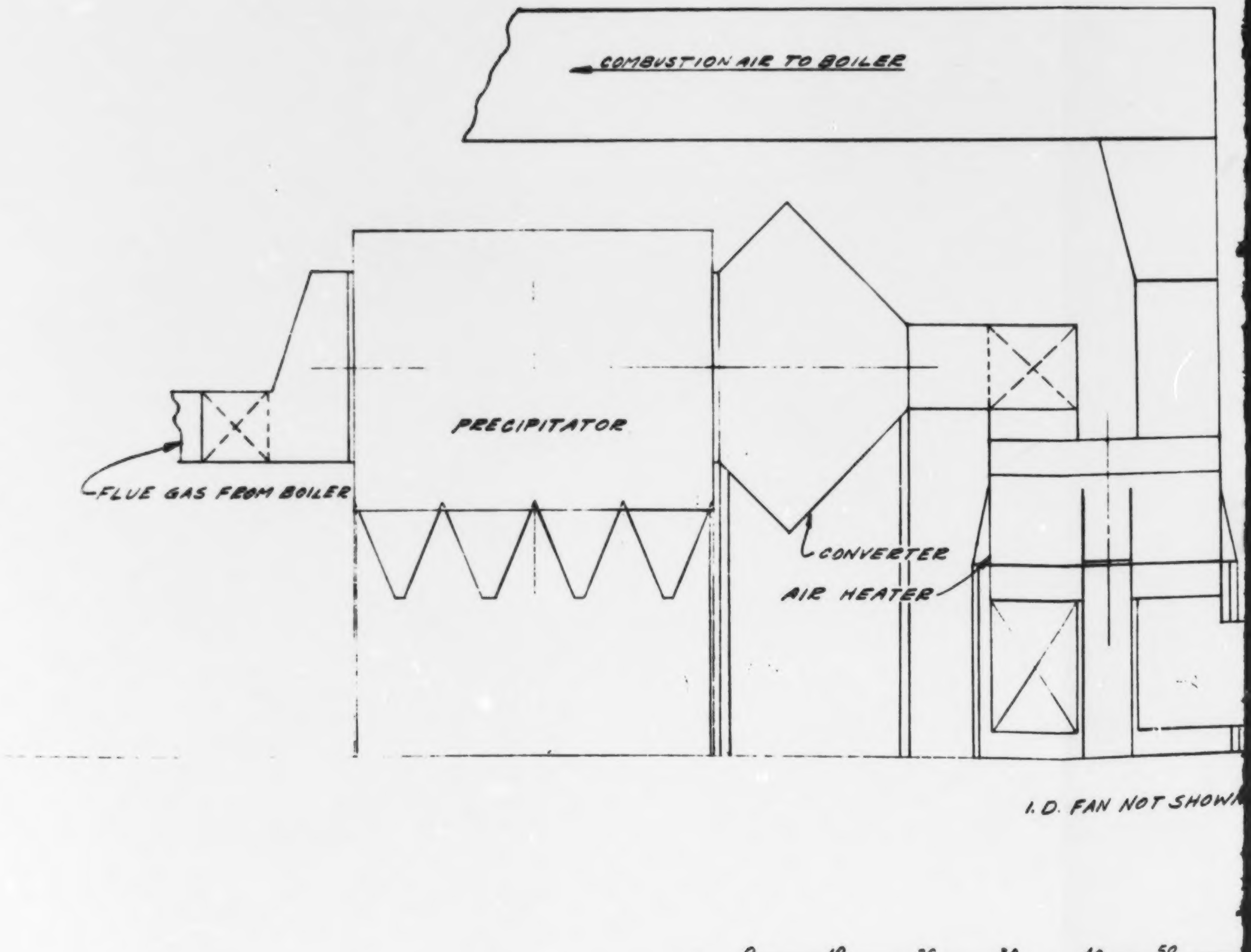
MONSANTO ENVIRO-CHEM SYSTEMS INC.
10 S. RIVERSIDE PLAZA
CHICAGO, ILLINOIS 60606

CHEMICO/NAPCA STUDY COAL GASIFICATION PLANT

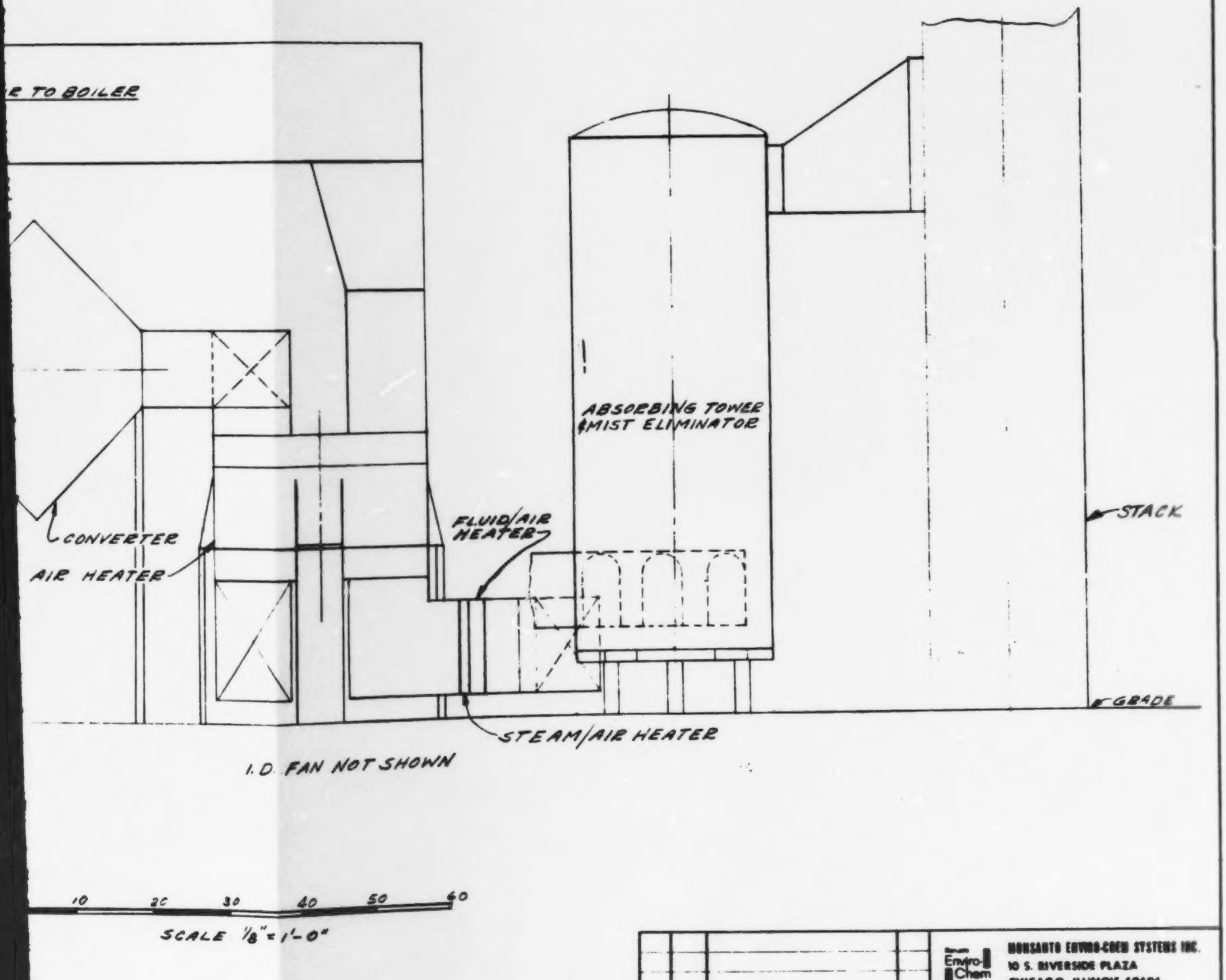
STREAM FLOW DIAGRAM
INTEGRATED CAT-OX SYSTEM
CASE-'B' 300,000 LBS. STM/HR

DRAWN R&O
CHECKED
SCALE

0694
3-30


COMBUSTION AIR TO BOILER
PRECIPITATOR
FLUE GAS FROM BOILER
CONVERTER
AIR HEATER
0
10
20
30
40
50
SCALE 1/8" = 1'-0"

I. D. FAN NOT SHOW


E TO BOILER
CONVERTER
AIR HEATER
FLUID/AIR HEATER
ABSORBING TOWER & MIST ELIMINATOR
STACK
GRADE
STEAM/AIR HEATER
I.D. FAN NOT SHOWN
10
20
30
40
50
60
SCALE 1/8" = 1'-0"

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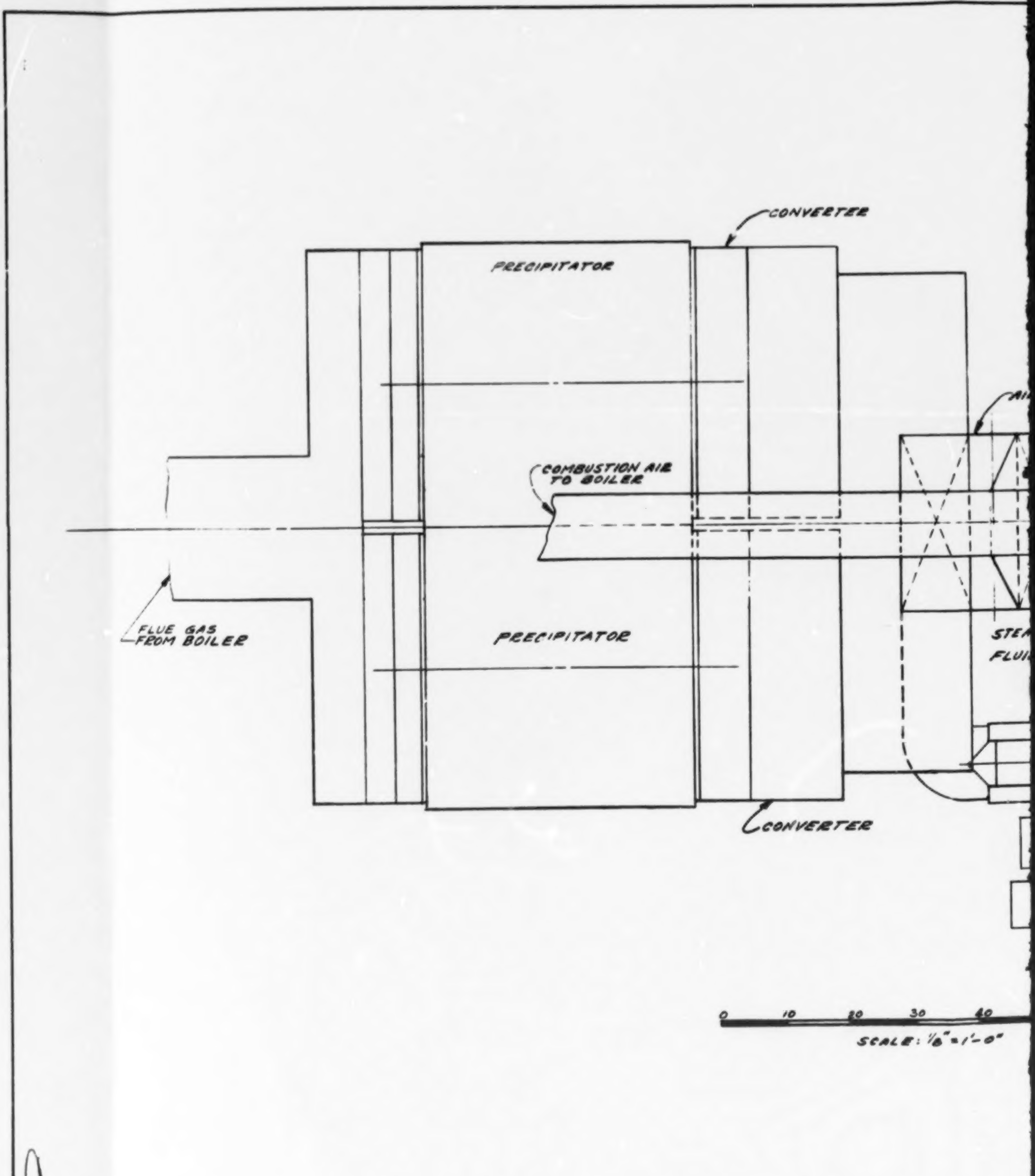
MONSANTO ENVIRO-CHEM SYSTEMS INC.
CHICAGO, ILLINOIS

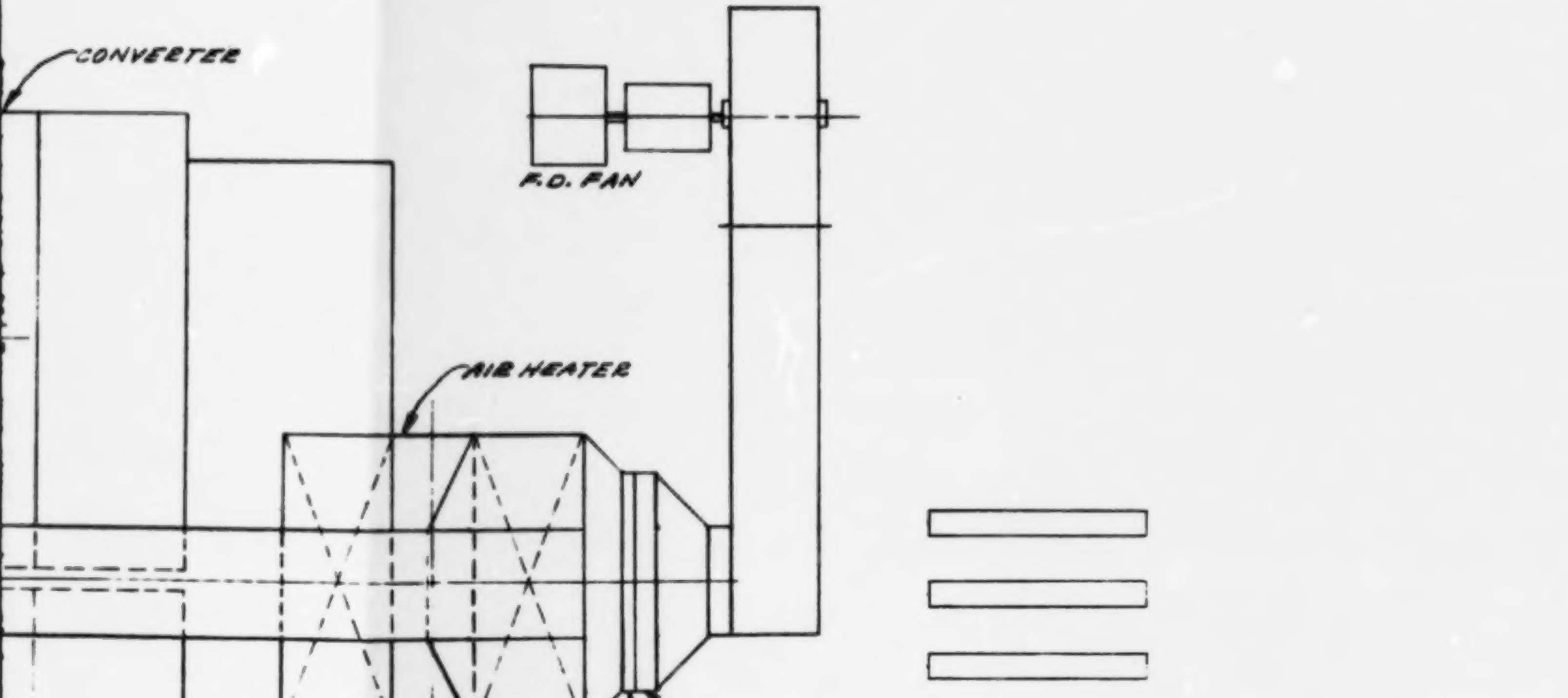
MONSANTO ENVIRO-CHEM SYSTEMS INC.
10 S. RIVERSIDE PLAZA
CHICAGO, ILLINOIS 60606

CHEMICO/AMPCA STUDY/COAL BENEFICIATION PLT

PLANT LAYOUT - ELEVATION
INTEGRATED CAT-OX SYSTEM
CASE "B" 500,000 LBS. STM/HR

0694
3-32


CONVERTER
PRECIPITATOR
COMBUSTION AIR TO BOILER
FLUE GAS FROM BOILER
PRECIPITATOR
CONVERTER
AI
STE
FLUI
0
10
20
30
40
SCALE: 1/8" = 1'-0"


CONVERTER
F.D. FAN
AIR HEATER
STEAM/AIR HEATER
FLUID/AIR HEATER
ACID COOLERS
CONVERTER
I.D. FAN
STACK
ABSORBING TOWER & MIST ELIMINATOR
10
20
30
40
50
60
SCALE: 1/8" = 1'-0"

MONSANTO ENVIRO-CHEM SYSTEMS INC.
10 S. RIVERSIDE PLAZA
CHICAGO, ILLINOIS 60606

[illegible] STUDY/COAL BENEFICIATION PLT

PLANT LAYOUT - PLAN
INTEGRATED CAT-OX SYSTEM
CASE-"B" 500,000 LBS STM/HR

	BY	DATE	APPROVED	DATE	[illegible]
DRAWN	G.H.	[illegible]	[illegible]	[illegible]	[illegible]
CHECKED	[illegible]	[illegible]	[illegible]	[illegible]	3-31
SCALE	[illegible]				

4. Cat-Ox CAPITAL COST

"The approximate total capital cost for an integrated Cat-Ox system for the specified conditions and with a Scope of Supply as listed in the Preliminary Scope Report, based on current labor rates, is $6, 400, 000 installed.

"Certain equipment items are included in the Cat-Ox system which are also included in the boiler scope and pricing. The boiler pricing you are obtaining from Foster Wheeler includes forced draft fan, air heater, and flues and ducts to the air heater. These items are also included in the Cat-Ox system total cost above. The approximately installed cost of this "overlapping" equipment, based on current labor rates, is $900, 0C0. Thus, the incremental approximate capital cost of Cat-Ox for this application is $5, 500, 000." --- Monsanto Enviro-Chem Systems, Inc. Preliminary Scope Report, CASE B June 26, 1970

The advice cited above is given effect in the capital cost estimate of CASE B that is entered in Volume One, Table VIII-1 as shown below.

CASE B	Erected Cost Basis
Combustor/Boiler	$ 5, 110, 000
Adjustment for "overlapping" equipment	900, 000
Net Combustor/Boiler	$ 4, 210, 000
Cat-Ox Acid Plant	6, 400, 000
Acid Concentrators	4, 000, 000
Tail-Gas Treatment	2, 100, 000
Sulfur Recovery Total	$12, 500, 000
Total less land	$16, 710, 000

XV

CASE C PROTOTYPE SYSTEM

1. PROCESS DESCRIPTION

1.1 Fuel Milling and Combustion

An HSC Fuel of the CASE C and D composition (See Table XI-1) containing 21.1% iron pyrite is milled to p.c. size and conveyed by preheated air to the horizontal burners of the 50 MW Furnace, through the combustion and absorption zones and the preheaters, to the Cyclone Collector at the boiler exit. Combustion and steam generation proceed as described in PART XI. The steam is of subcritical quality for turbo-generator drive as shown in the flow diagram CASE C, Sheet 1, together with the distribution of ash, the flue gas composition, and other data.

1.2 Flue Gas Cleaning (See Chemico process Sheet 1 following page XV - 4)

Combustion gas at 500° F containing about 1% SO_2 flows from the cyclone collector at the boiler exit to a Venturi-Scrubber wherein the remaining fly ash and acid mist are removed by entrainment in weak sulfuric acid solution in which SO_2 is only slightly soluble. This scrubbing solution is purged continually to the solids disposal circuit that includes provision for lime-neutralization of the entrained sulfur oxides so that these compounds will precipetate and be collected together with the fly ash in the Thickener and waste solids Centrifuge.

1.3 Recovery of SO_2 as Magnesium Sulfur Salts.

1.3.1 Absorption

The cool, cleaned flue gas, still of about 1% SO_2 concentration, is brought into intimate contact with the absorbing liquid slurry containing $MgSO_3$, $MgSO_4$ and MgO in a two-stage Venturi-type mass transfer device. The gas and liquid flow co-currently; i.e., both phases move through the absorption equipment in the same direction. The flue gas is accelerated as the gas approaches the throat section of the Venturi. This higher level of gas energy is transferred to the liquid, possessing lower energy, causing it to break up into droplets. On the surface of these droplets, the SO_2 from the gas phase diffuses into and chemically reacts with the solid and solute phases of $MgSO_3$ and MgO.

The SO_2 is absorbed in accordance with the following chemical reactions:

$$MgO + SO_2 \longrightarrow MgSO_3$$
$$MgSO_3 + SO_2 + H_2O \longrightarrow Mg(HSO_3)_2$$
$$Mg\,(HSO_3)_2 + MgO \longrightarrow 2\,MgSO_3 + H_2O$$
$$MgO + SO_3 \longrightarrow MgSO_4$$
$$MgSO_3 + 1/2O_2 \longrightarrow MgSO_4$$

The recirculating liquor contains $MgSO_3$, $MgSO_4$ and MgO. The make-up to the absorption system is a suitable MgO slurry.

Downstream of this absorption reaction the SO_2 is freed in a gas concentrate for conversion to some marketable form of sulfur value such as sulfuric acid, sulfur dioxide, or in CASE C and D, sulfur. Since none of these conversions can be carried to completion it is convenient in each instance to return the loss of product yield to this absorption step in the form of SO_2. In CASE C, Sheet 1, it is shown that uncaptured sulfur value is returned from the sulfur plant to the absorption step for recycling in this manner.

The flue gas and liquor leaving the Venturi enter the Cyclonic Separator, where any entrained liquor is separated. The flue gas is exhausted to the atmosphere through the Stack.

1.3.2 Centrifuging

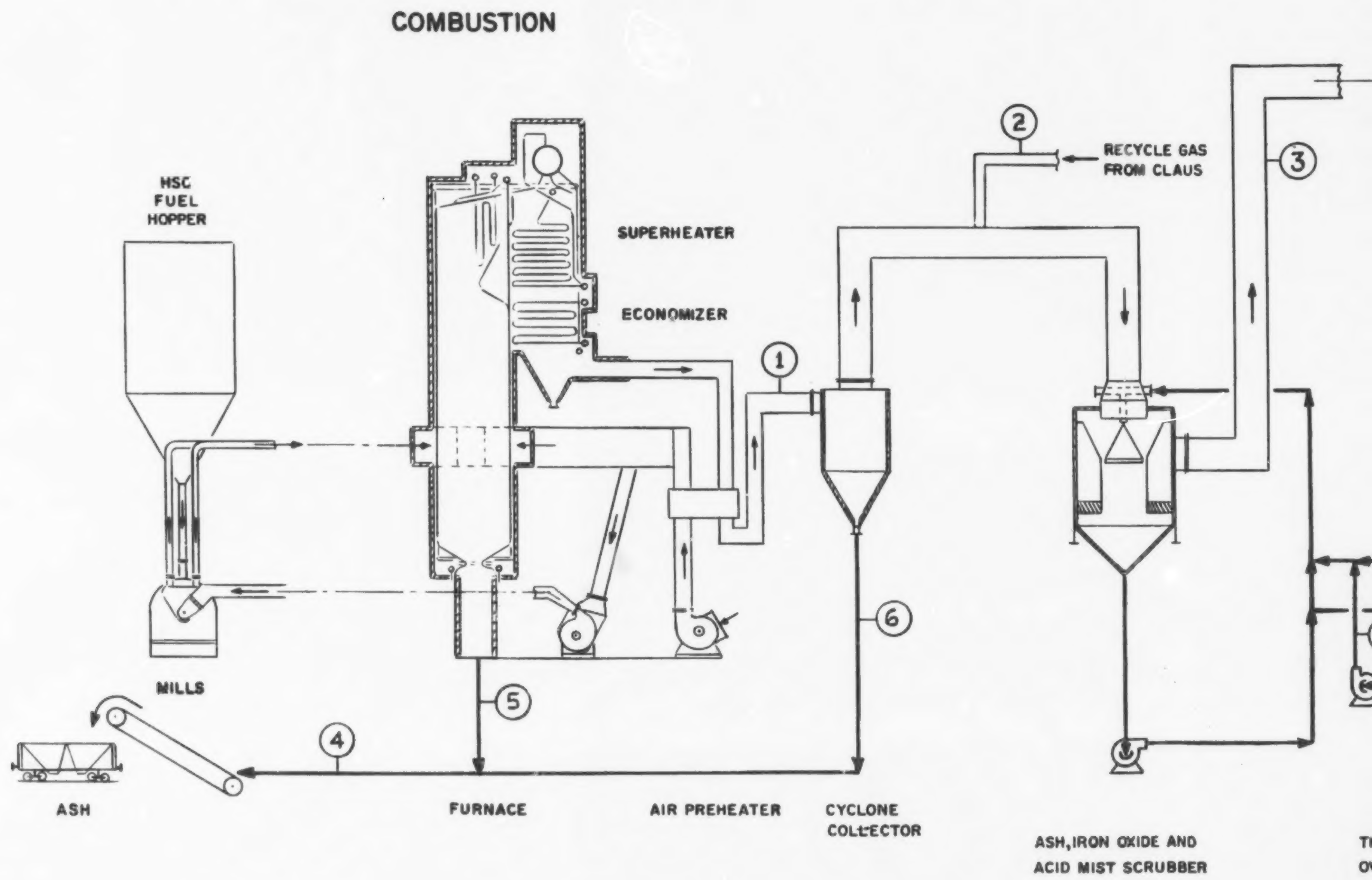
A continuous bleed of 10-15% slurry is maintained from the absorption system to the product Centrifuge, where a centrifuged cake containing approximately 5% surface moisture is obtained. The mother liquor is returned to the absorption system through a holding tank.

1.3.3 Drying

The centrifuged cake, consisting of $MgSO_3 \cdot 6H_2O$, $MgSO_4 \cdot 7H_2O$, MgO and surface moisture is fed to the direct-fired Dryer by gravity flow, where combined and surface water are removed. The flue gas leaving the dryer is discharged to the atmosphere through a Dry Cyclone.

The dryer product, consisting of $MgSO_3$, $MgSO_4$ and MgO, is free flowing and stable, and may be processed on site or shipped. If the dryer product is shipped, return shipment of MgO, or other disposition of it, will be necessary.

COMBUSTION


HSC FUEL HOPPER
SUPERHEATER
ECONOMIZER
RECYCLE GAS FROM CLAUS
①
②
③
④
⑤
⑥
MILLS
ASH
FURNACE
AIR PREHEATER
CYCLONE COLLECTOR
ASH, IRON OXIDE AND ACID MIST SCRUBBER

HSC COMBUSTOR

FUEL:

TOTAL FUEL FLOW	74,400 LBS/HR
IRON PYRITE	15,500 "
COAL COMBSTIBLES	44,000 "
NON-PYRITIC ASH	14,900 "
HIGHER HEATING VALUE	9,000 BTU/LB
ENERGY INPUT	670×10^6 BTU/HR

ASH DISTRIBUTION:

DRY ASH	21 400 LBS/HR
WET ASH	4,100 "
LIME SOLIDS	1,900 "
TOTAL WASTE SOLIDS	27,400 "
% IRON IN DRY ASH	29

STEAM SECTION:

STEAM FLOW	500,000 LBS/HR
STEAM PRESSURE	1450 PSIG
STEAM TEMP.	1000 °F
NET HEAT OUTPUT	551×10^6 BTU/HR
REHEAT	NONE
FEEDWATER	430 °F
FLUE GAS EXIT	500 °F

ELECTRICAL SECTION:

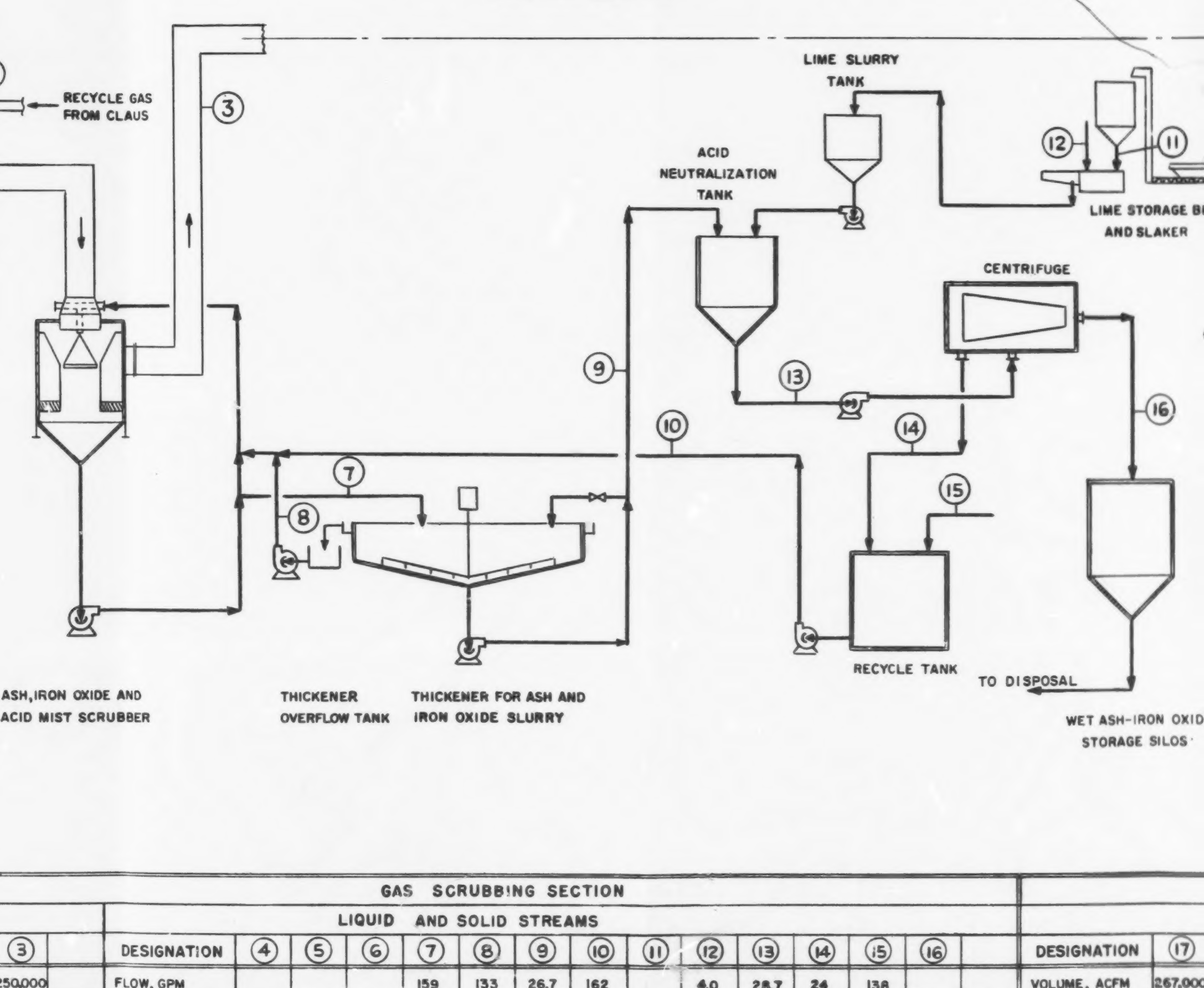
GENERATOR OUTPUT	50 MWH/HR
GROSS HEAT RATE	13,400 BTU/KWH
LOADING	8,000 HRS/YEAR

GAS STREAMS

DESIGNATION	①	②	③	
VOLUME, ACFM	279,000	47,400	250,000	
TEMP. °F	500	600	133	
HUMIDITY LB/LB	0.0239	0.219	0.132	
PARTICULATE GR/SCF	15.6	0.0	0.04	
SO_2 ppm	11,000	12,970	9,900	
H_2SO_4 mg/SCF			3.0	
SO_3 ppm	443	498	NIL	
PRES:-IN H_2O	0.0	0.0	42	

DESIGNATION	④
FLOW, GPM	
TEMP. °F	
%SOLIDS IN LIQUID	
SOLIDS, LB/HR	21,200
% H_2SO_4 IN LIQUID	
% H_2C IN SOLIDS	
% Fe_2O_3 IN SOLIDS	40.9

GAS SCRUBBING

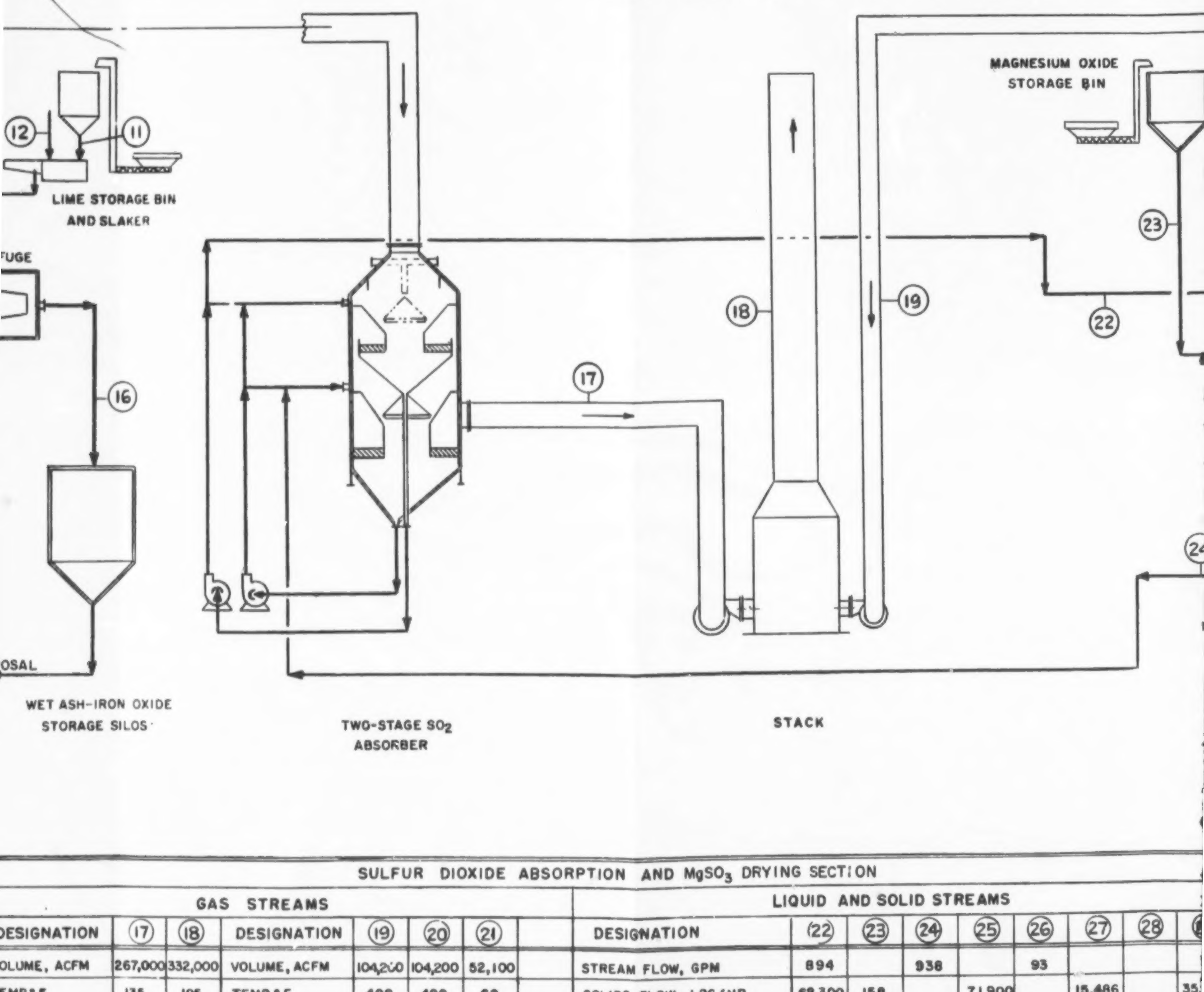

RECYCLE GAS FROM CLAUS
③
LIME SLURRY TANK
ACID NEUTRALIZATION TANK
⑫
⑪
LIME STORAGE B
AND SLAKER
CENTRIFUGE
⑨
⑬
⑩
⑭
⑯
⑦
⑧
⑮
ASH, IRON OXIDE AND
ACID MIST SCRUBBER
THICKENER OVERFLOW TANK
THICKENER FOR ASH AND IRON OXIDE SLURRY
RECYCLE TANK
TO DISPOSAL
WET ASH-IRON OXID
STORAGE SILOS

GAS SCRUBBING SECTION

LIQUID AND SOLID STREAMS

③		DESIGNATION	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭	⑮	⑯		DESIGNATION	⑰
250,000		FLOW, GPM				159	133	26.7	162		4.0	28.7	24	138			VOLUME, ACFM	267,000
133		TEMP. °F				133	133	133	106			200	<200		<200		TEMP. °F	135
0.132		%SOLIDS IN LIQUID				5.0	0.3	25.0				33	0.0				HUMIDITY LB/LB	0.14
0.04		SOLIDS, LB/HR	21,200	5,000	16,200	4,100	216	3,890		670		6,060	0.0		6,036		PARTICULATE GR/SCF	0.04
9,900		%H_2SO_4 IN LIQUID				10.	10.	10.				0.0	0.0		0.0		SO_2 ppm	102
3.0		%H_2C IN SOLIDS													5.0		H_2SO_4 mg/SCF	3.0
NIL		%Fe_2O_3 IN SOLIDS	40.9	40.9	40.9												SO_3 ppm	NIL
42																	PRESS:-IN H_2O	58

SO_2 ABSORPTION AND MAGNESIUM SULFITE RECOV


12
11
LIME STORAGE BIN AND SLAKER
FUGE
16
OSAL
WET ASH-IRON OXIDE STORAGE SILOS
TWO-STAGE SO_2 ABSORBER
17
18
19
STACK
MAGNESIUM OXIDE STORAGE BIN
23
22
24

SULFUR DIOXIDE ABSORPTION AND $MgSO_3$ DRYING SECTION

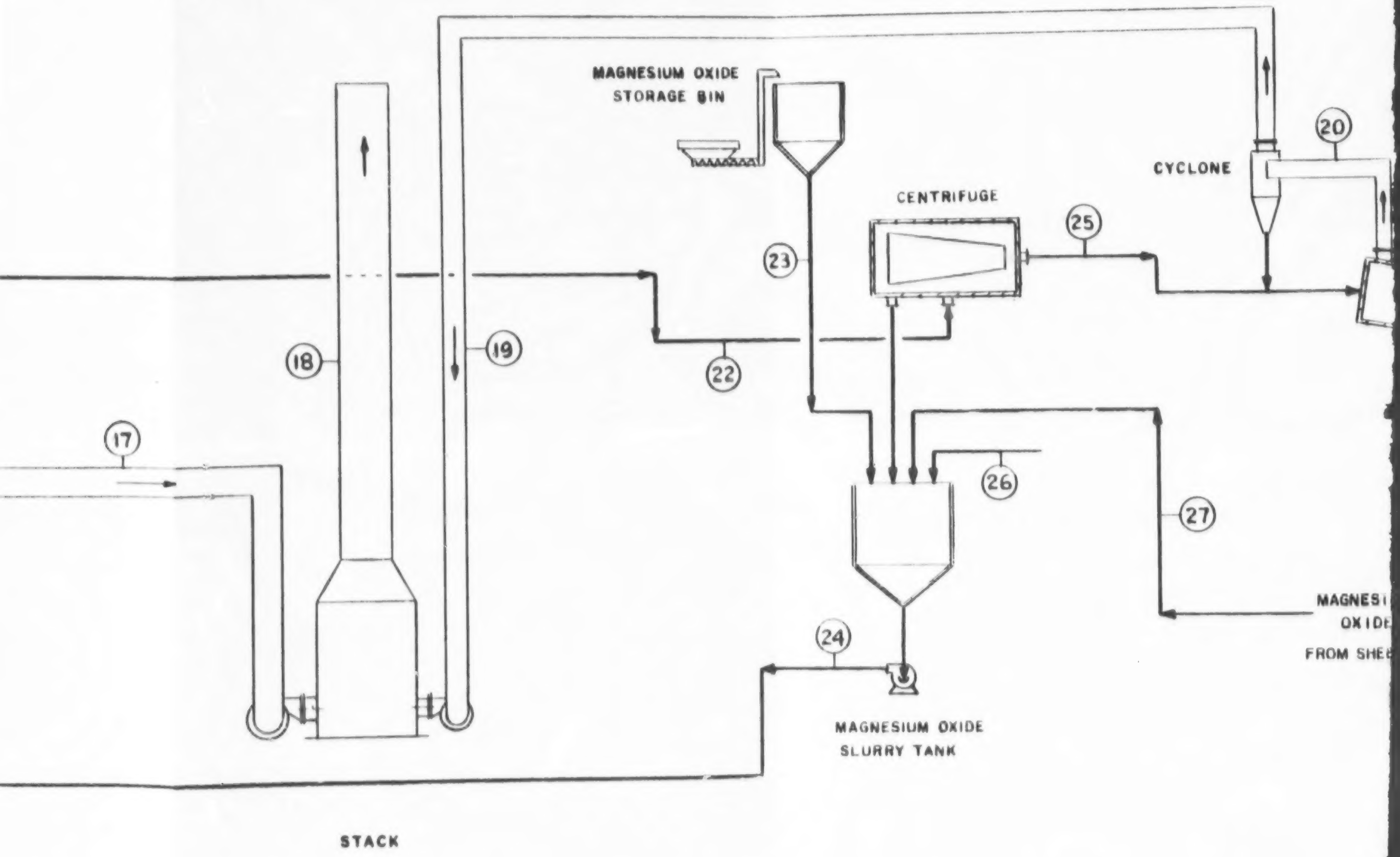
GAS STREAMS

DESIGNATION	⑰	⑱	DESIGNATION	⑲	⑳	㉑	
OLUME, ACFM	267,000	332,000	VOLUME, ACFM	104,200	104,200	52,100	
EMP. °F	135	195	TEMP. °F	400	400	60	
UMIDITY LB/LB	0.14	0.15	HUMIDITY LB/LB	0.154	0.154		
ARTICULATE R/SCF	0.04	0.11	PARTICULATE GR/SCF	0.321	3.1	0.0	
O_2 ppm	102	77	%SO_2	NIL	NIL	0.0	
$_2SO_4$ mg/SCF	3.0	2.25					
O_3 ppm	NIL	NIL					
RESS:-IN H_2O	58						

LIQUID AND SOLID STREAMS

DESIGNATION	㉒	㉓	㉔	㉕	㉖	㉗	㉘	
STREAM FLOW, GPM	894		938		93			
SOLIDS FLOW, LBS/HR	68,300	158		71,900		15,486		35,
TEMPERATURE °F	135							
% SOLIDS IN LIQUID STREAM	13		3.0					
HYDRATED MAGNESIUM SULFUR SALTS, LBS/HR	64,980			64,980				
ANHYDROUS. MAGNESIUM SULFUR SALTS, LBS/HR								31,
MgO, LBS/HR	3,320	158*		3,320		15,486		3
FUEL OIL, GPM							11.4	
	*1% OVERALL LOSS							

SO_2 ABSORPTION AND MAGNESIUM SULFITE RECOVERY

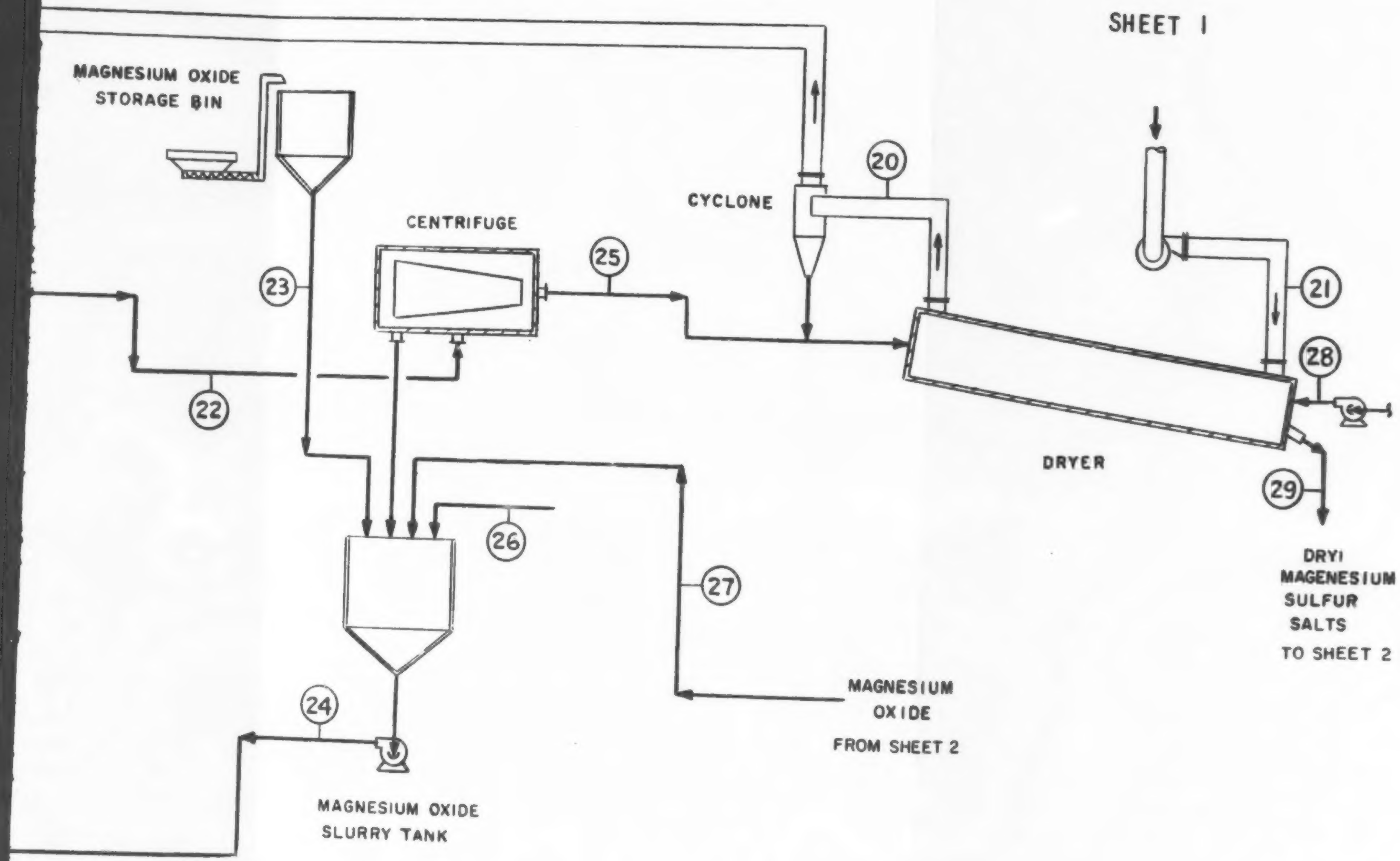


MAGNESIUM OXIDE
STORAGE BIN
CENTRIFUGE
CYCLONE
20
25
23
22
18
19
17
26
27
24
MAGNESI
OXIDE
FROM SHE
MAGNESIUM OXIDE
SLURRY TANK
STACK

IDE ABSORPTION AND $MgSO_3$ DRYING SECTION												
		LIQUID AND SOLID STREAMS										
21)		DESIGNATION	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	
2,100		STREAM FLOW, GPM	894		938		93				
60		SOLIDS FLOW, LBS/HR	68,300	158		71,900		15,486		35,090	
		TEMPERATURE ° F	135								
0.0		% SOLIDS IN LIQUID STREAM	13		3.0						
0.0		HYDRATED MAGNESIUM SULFUR SALTS, LBS/HR	64,980			64,980					
		ANHYDROUS. MAGNESIUM SULFUR SALTS, LBS/HR								31,770	
		MgO, LBS/HR	3,320	158*		3,320		15,486		3,320	
		FUEL OIL, GPM							11.4		
			*1% OVERALL LOSS								

IUM SULFITE RECOVERY

CASE C
SHEET 1


MAGNESIUM OXIDE
STORAGE BIN
CENTRIFUGE
CYCLONE
DRYER
⑳
㉑
㉒
㉓
㉔
㉕
㉖
㉗
㉘
㉙
DRY MAGENESIUM SULFUR SALTS TO SHEET 2
MAGNESIUM OXIDE FROM SHEET 2
MAGNESIUM OXIDE SLURRY TANK

EAMS					
㉕	㉖	㉗	㉘	㉙	
	93				
71,900		15,486		35,090	
64,980					
				31,770	
3,320		15,486		3,320	
			11.4		

HIGH SULFUR COMBUSTOR STUDY

FLOW SHEET AND QUANTITIES

o

ENERGY PRODUCT
ELECTRICITY 50 MEGAWATTS CAPACITY
400,000 MWH/YEAR
INTERMEDIATE CHEMICAL PRODUCT
DRY MAGNESIUM SALTS
EQUIVALENT TO 100 TONS/DAY OF SULFUR

1.4 Calcining of Magnesium Sulfur Salts. (See flow diagram CASE C, Sheet 2)

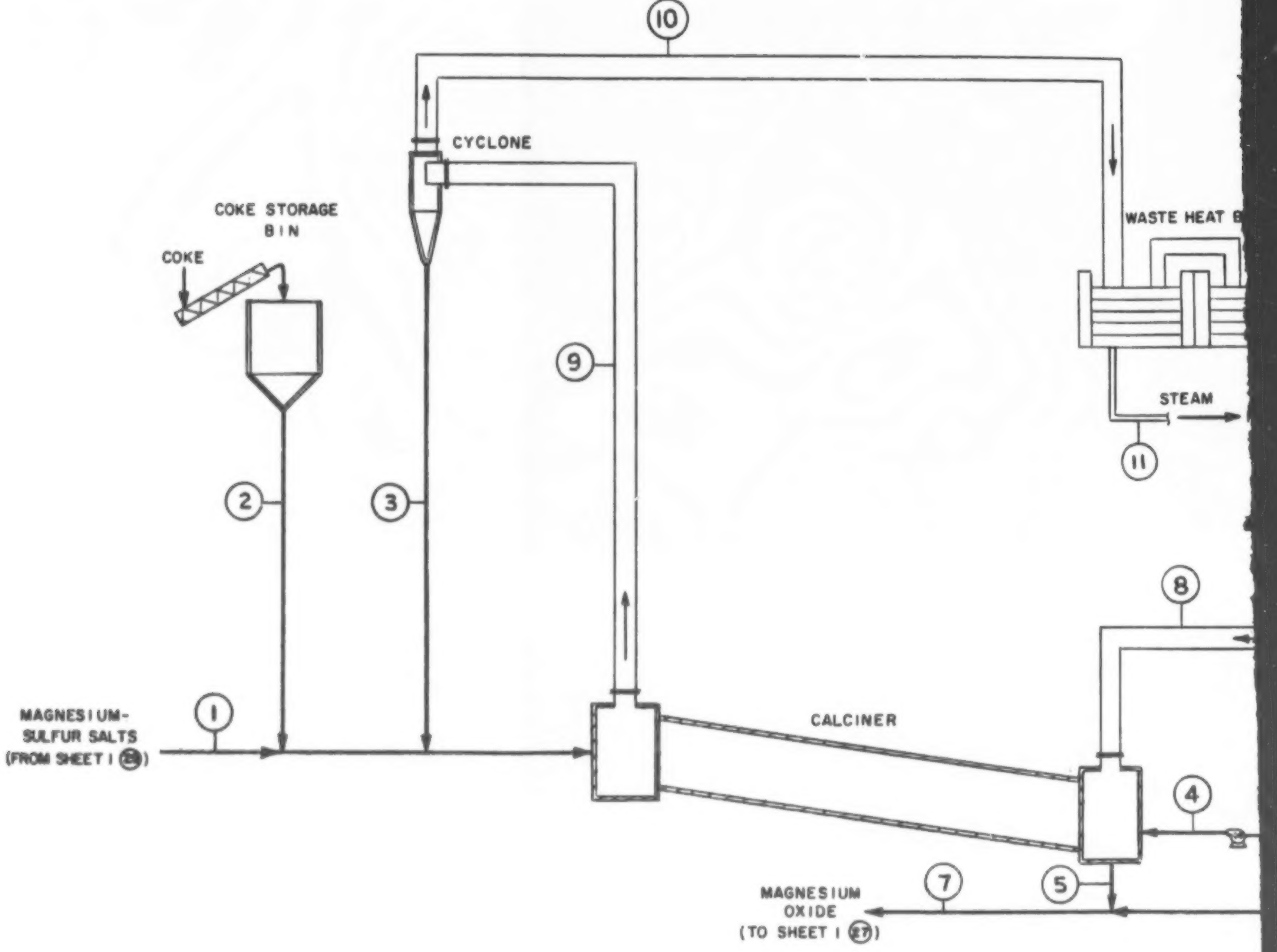
If the dryer product is processed on site it is conveyed to the Rotary Calciner, to which carbon as coke is also added, where the magnesium salts are dissociated into MgO and SO_2, in accordance with the following chemical reactions:

$$MgSO_3 + \text{Heat} \longrightarrow MgO + SO_2$$

$$MgSO_4 + 1/2C \;\; \text{Heat} \longrightarrow MgO + SO_2 + 1/2CO_2$$

The calciner exit gas, rich in SO_2 (15-17% by volume) enters a Cyclone Dust Collector followed by a Waste Heat Boiler and a Baghouse for final cleaning of the gas. The separated MgO dust is returned to the slaking system on Sheet 1 as is the solid MgO product of the calciner.

The SO_2 gas stream may be processed directly to sulfuric acid (CASE D3), or to intermediate products, sulfur dioxide or elementary sulfur.


10
CYCLONE
COKE STORAGE BIN
COKE
WASTE HEAT B
9
STEAM
11
2
3
8
MAGNESIUM-SULFUR SALTS (FROM SHEET I ㉘)
1
CALCINER
4
MAGNESIUM OXIDE (TO SHEET I ㉗)
7
5

SULFUR DIOXIDE RECOVERY SECTION

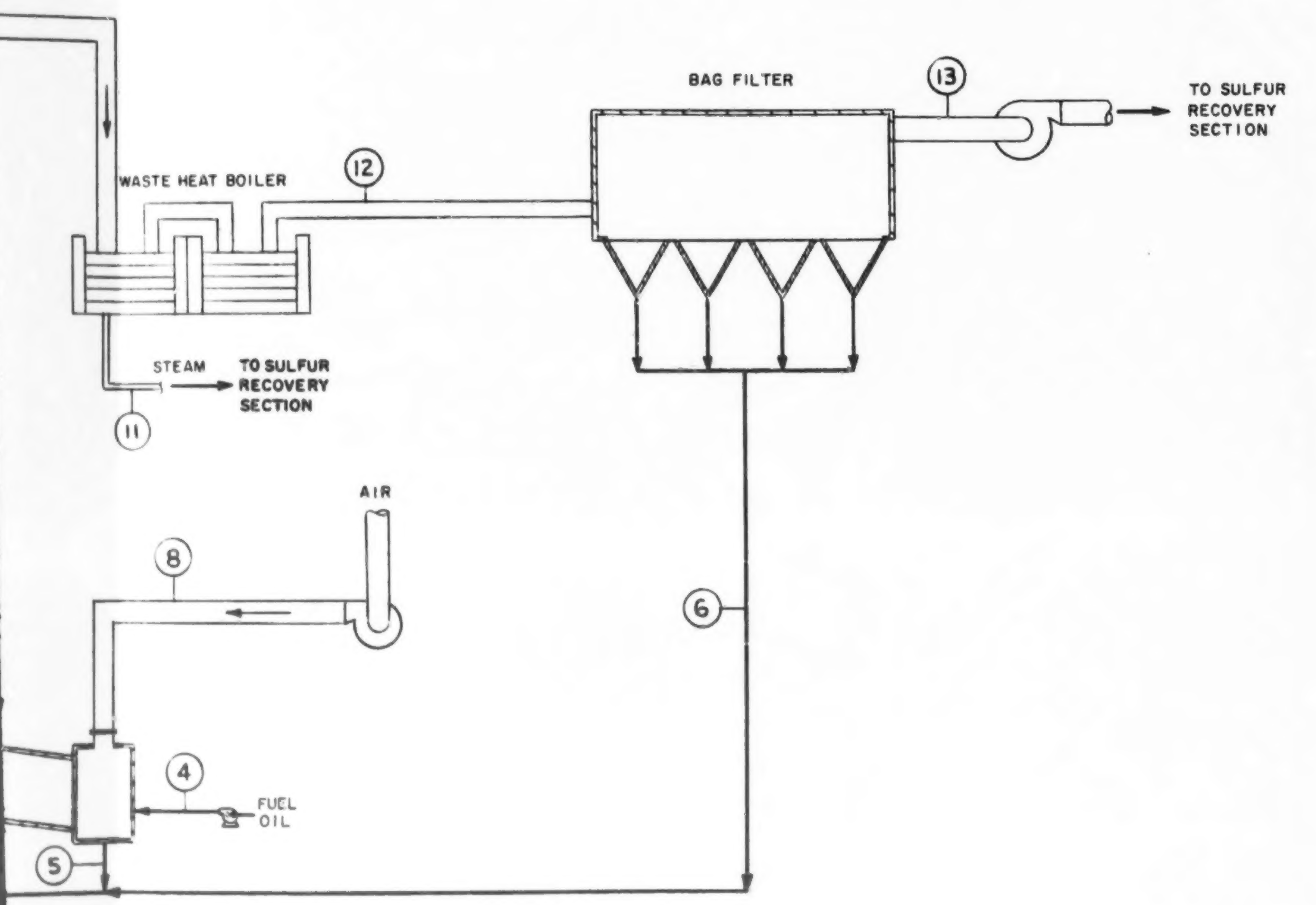
LIQUID AND SOLID STREAMS

DESIGNATION	①	②	③	④	⑤	⑥	⑦	
SOLIDS FLOW, LBS/HR	35,090	90	1,390		15,330	156	15,486	
TEMPERATURE °F		60						
ANHYDROUS MAGNESIUM SULFUR SALTS, LBS/HR	31,770							
MgO, LBS/HR	3,320				15,330	156	15,486	
FUEL OIL, GPM				7.6				

GAS STREA

DESIGNATION	⑧	⑨	⑩
VOLUME, ACFM	10,880	51,100	51,100
TEMP. °F	60	1500	1500
HUMIDITY, LB/LB		0.057	0.057
PARTICULATE GR/SCF	0.0	13.3	1.3
%SO_2	0.0	14.3	14.3
STEAM, 550 LB. SAT. LBS/HR			

CASE C
SHEET 2


BAG FILTER
⑬
TO SULFUR RECOVERY SECTION
⑫
WASTE HEAT BOILER
STEAM
TO SULFUR RECOVERY SECTION
⑪
AIR
⑧
⑥
④
FUEL OIL
⑤

SECTION							
	GAS STREAMS						
TION	⑧	⑨	⑩	⑪	⑫	⑬	
CFM	10,880	51,100	51,100		25,000	25,000	
	60	1500	1500		500	500	
LB/LB		0.057	0.057		0.057	0.057	
TE	0.0	13.3	1.3		1.3	NIL	
	0.0	14.3	14.3		14.3	14.3	
LB. R				17,000			

HIGH SULFUR COMBUSTOR STUDY

FLOW SHEET AND QUANTITIES

o

INTERMEDIATE CHEMICAL PRODUCT

15% SULFUR DIOXIDE GAS

EQUIVALENT TO 100 TONS/DAY OF SULFUR

1.5 Reduction of SO_2 to Sulfur

The clean, cool SO_2 gas evolved from the calciner and filtered will have the following approximate composition:

	Mole %
SO_2	13
CO_2	9
H_2O	15
N_2	63
O_2	Small

This gas is compressed to 25 psig. and a portion of it combined with a gaseous reducing agent in preparation for the Claus process reduction of SO_2 to sulfur.

1.5.1 Reformed Gas

An Autothermal Reformer receives air and natural gas (essential for heat liberation) and steam and natural gas for catalytic conversion or "reforming" to a mixture of carbon monoxide and hydrogen diluted with nitrogen and small amounts of carbon dioxide and water. The base reactions are as follows:

$$2CH_4 + 3\ 1/2O_2 \longrightarrow CO_2 + 4H_2O + CO + \text{Heat}$$

$$CH_4 + H_2O + \text{Heat} \longrightarrow CO + 3H_2$$

This reducing gas is generated at about 80 psig.

1.5.2 Sulfur Dioxide to Hydrogen Sulfide

The mixture of reducing gas from auto-thermal reforming and the controlled portion of SO_2-containing gas at 25 psig. are reacted catalytically to hydrogen sulfide and diluents in accordance with reactions as follows:

$$3H_2 + SO_2 \longrightarrow H_2S + 2H_2O \qquad (1)$$

$$3CO + SO_2 + H_2O \longrightarrow H_2S + 3CO_2 \qquad (2)$$

$$3CO + SO_2 \dashrightarrow COS + 2CO_2 \qquad (3)$$

$$4H_2S + 2SO_2 \longrightarrow 3S_2 + 4H_2O \qquad (4)$$

Reactions (3) and (4) are quantitatively minor at this stage. However a net result is strong evolution of heat which is recovered in a steam boiler prior to recombining the H_2S-bearing gas with the untreated portion of the SO_2 gas stream accepted at point (1) on Sheet 3.

1.5.3 Claus Reaction

The portion of the SO_2 gas stream that is diverted for reduction to H_2S is controlled as to quantity so that the mole ratio of H_2S to SO_2 in the recombined gas stream is 2. This mixture at 760° F is then reacted on the Claus bauxite catalyst essentially as follows:

$$2H_2S + SO_2 \longrightarrow 2H_2O + 3S$$

The presence of carbon compounds in the actual reaction field gives rise to carbonyl sulfide (COS) and carbon disulfide (CS_2) and these in turn react to some degree with SO_2 to yield sulfur. (See Volume One, Part VI-4.6.5). Two Claus Reactor stages with intermediate heat exchange and condensation in the first and second Sulfur Separators are provided.

From these, very high grade liquid sulfur flows to storage.

1.5.4 Incineration

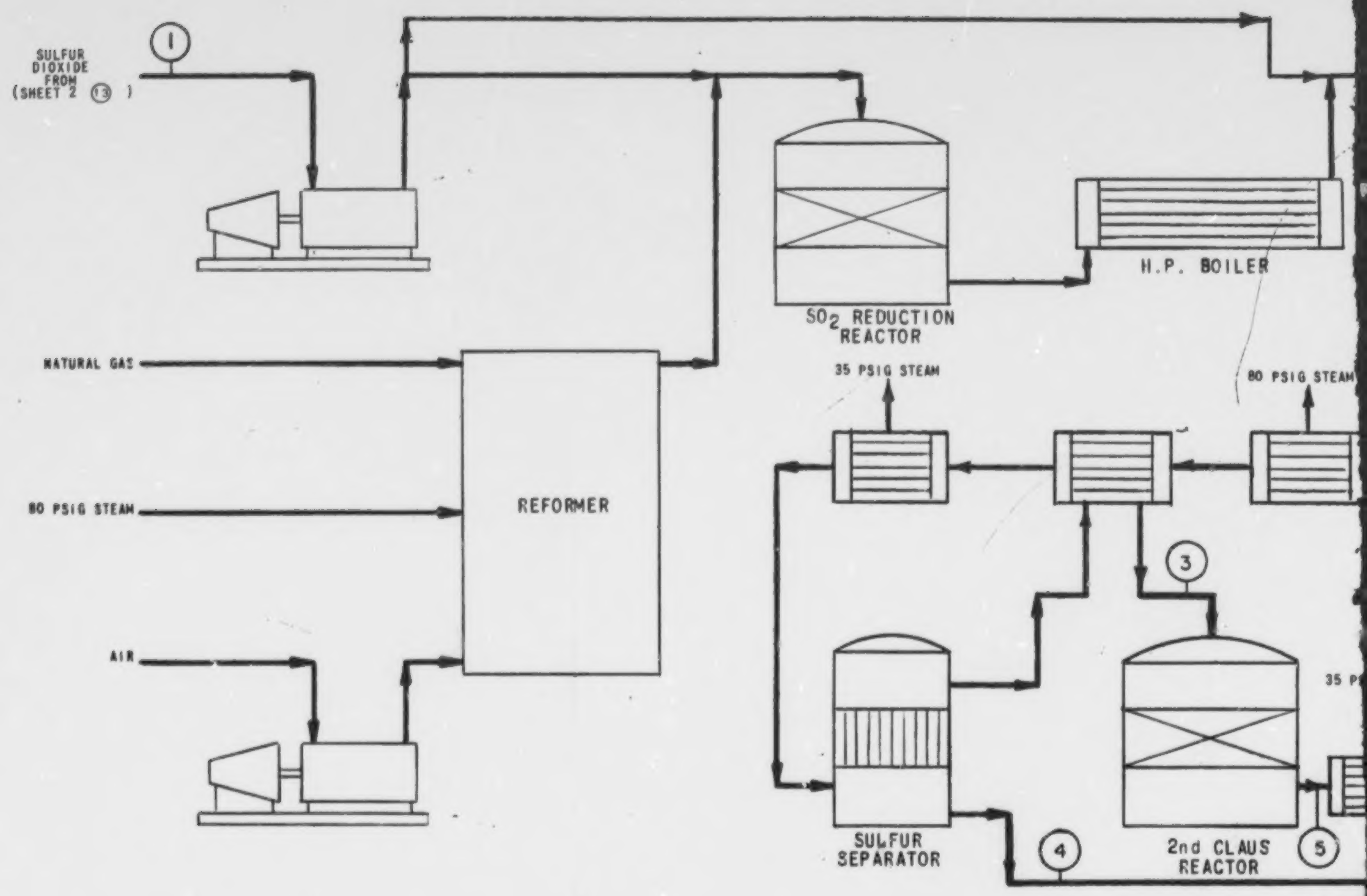
The Claus equilibria tend to yield 81.6% of theory as sulfur per pass. The exit gas of the second sulfur separator proceeds at 300° F to the Preheater of the Incinerator and into the incinerator at 740° F where all reduced sulfur compounds (H_2S, COS, CS_2 and uncondensed S) are burned in air to SO_2. Essentially 18.4% of the sulfur entering Sheet 3 as SO_2 feed gas is returned as SO_2 to the main absorber on Sheet 1, reacted therein to magnesium sulfur salts and recycled.

The SO_2 reduction plant as represented by Sheet 3 is thus effectively free of sulfur losses in the form of volatile sulfides or oxides.

1.6 Turndown Characteristics

The conversion of SO_2 in the flue gas to magnesium sulfur salts can operate at any reduced rate down to quite low levels both as to SO_2 throughput quantity and flue gas concentration but of course at reduced efficiency. The dry magnesium salts can be bulk stored (under cover) until the calcination and reduction to sulfur can be operated at a normal rate.

At very low levels of flue gas SO_2, the main absorber can be charged with lime instead of magnesium alkali, and the precipitated lime salts discarded in the manner illustrated in CASES A, B and E.

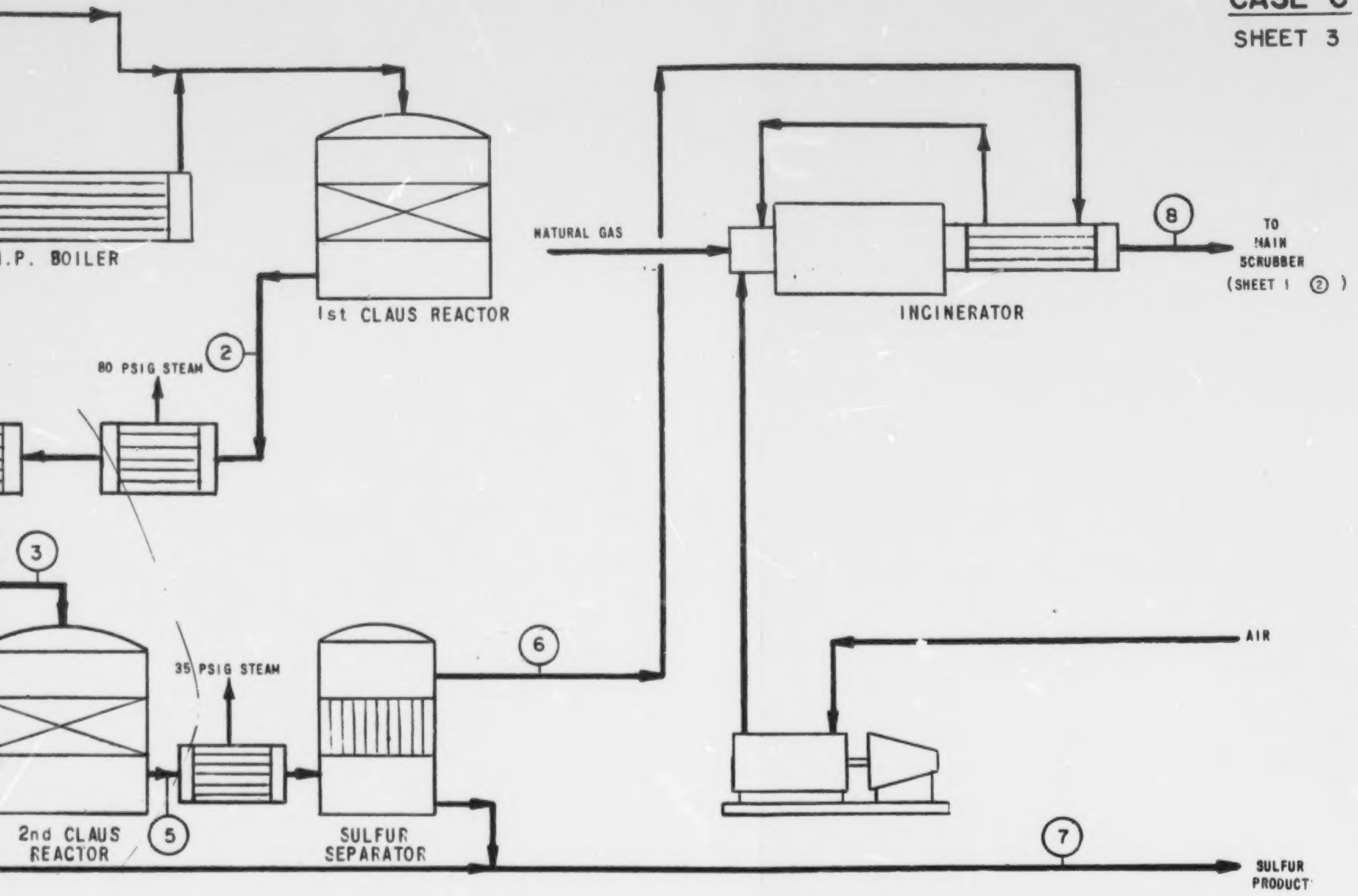

①
SULFUR DIOXIDE FROM (SHEET 2 ⑬)
NATURAL GAS
80 PSIG STEAM
AIR
REFORMER
SO_2 REDUCTION REACTOR
H.P. BOILER
35 PSIG STEAM
80 PSIG STEAM
③
SULFUR SEPARATOR
④
2nd CLAUS REACTOR
⑤
35 P

PROCESS STREAM FLOWRATES FOR 100 TONS SULFUR PER DAY CAPACITY

DESIGNATION NO.	①	②	③	④	⑤	⑥	⑦	⑧
H_2S (10^3 LBS/HR)		35.4	35.4		9.1	9.1		
SO_2 "	20.4	33.3	33.3		8.4	8.4		28.9
H_2O "	6.5	142.6	142.6		156.3	156.3		173.6
H_2 "		.4	.4		.4	.4		
CO "								
SULFUR "		28.7	3.2	25.5	40.7	1.9	68.3	
INERTS "	52.6							
TOTAL FLOW (10^3 LBS/HR)	79.5							
ACFM	9,670							
GPM								
TEMP (°F)	414							
PRESSURE (PSIG)	25							

CASE C

SHEET 3



P. BOILER
1st CLAUS REACTOR
NATURAL GAS
INCINERATOR
8
TO
MAIN
SCRUBBER
(SHEET 1 ②)
2
80 PSIG STEAM
3
6
AIR
35 PSIG STEAM
2nd CLAUS
REACTOR
5
SULFUR
SEPARATOR
7
SULFUR
PRODUCT

HIGH SULFUR COMBUSTOR STUDY

FLOW SHEET AND QUANTITIES

o

CHEMICAL PRODUCT

100 NET TONS/DAY

OF

SULFUR

2. SUMMARY OF CAPITAL COST

CASE C PROTOTYPE	Erected Cost Basis
Combustor System (See Part XI)	$ 4,313,000
SO_2 Recovery*	
Dry Magnesium Salts	5,523,000
Calciner Plant	1,966,000
Sulfur Plant	3,400,000
	10,889,000
Total less land	$15,202,000

* See detailed estimate following.

CHEMICO – COST ESTIMATE SUMMARY

CLIENT: NAPCA	LOCATION: CASE C	TYPE OF ESTIMATE: Budget	ESTIMATE NO.: 0067C	DATE: 11/17/70	
DESCRIPTION OF PLANT: Sheets 1 and 2		SCOPE: 100 TPD Sulfur	ESTIMATED BY: JG		SHEET NO.: 1 of 14

CODE	DESCRIPTION	MATERIAL	LABOR	SUBCONTR.	TOTAL $	MATERIAL	LABOR	SUBCONTR.$	TOTAL $	GRAND TOTAL $
A	FOUNDATIONS							150 000		
B	BUILDINGS									
C	STRUCTURAL STEEL				250 000			220 000		
	SUB-TOTAL STRUCT.(A-C)				250 000			370 000		
	Ref. Page 4				1 180 000					
	5				63 000					
	6				35 000					
	7				165 000					
	8				68 200					
	9				49 200					
	10				35 240					
	11				666 100					
	12				100 850					
	13				72 700					
	14				59 000					
	SUB-TOTAL EQUIP.(D-R)				2 494 390	x 40		998 000		
S	INSULATION							150 000		
T	PIPING				400 000			600 000		
U	INSTRUMENTATION				88 600			110 000		
V	ELECTRICAL				100 000			400 000		
W	CHEMICALS & CATALYSTS									
X	PAINTING							45 000		
Y	MISC. SITE WORK									
Z	TRAVEL & SUBSISTENCE (LABOR)									
	SUB-TOTAL (S-Z)				588 600			1 305 000		
	TOTAL DIR. COSTS (A-Z)				3 332 990			2 673 000		
AA-AF	FIELD COSTS									
BA-BE	N.Y. OFFICE COSTS				280 000					
AG	START-UP SUPERVISION				P/D					
CC	START-UP M & L									
	N.Y.O. Expense				60 000					
	SUB-TOTAL				3 672 990			2 748 000		
	TAXES & ROYALTIES									
	CONTINGENCY 3% 5%				110 000			137 000		
BC	CHEMICO OVERHEAD				547 200					
	TOTAL COST				4 330 190			2 885 000		
	5% 2% FEES & PROFIT				216 010			58 000		
	SELLING PRICE				4 546 200			2 943 000		7 489 200

09 - 4613A 10-60 / 10-60

CHEMICO – COST ESTIMATE SUMMARY

CLIENT NAPCA	LOCATION CASE C	TYPE OF ESTIMATE Budget	ESTIMATE NO. 0067 C	DATE 11/17/70	
DESCRIPTION OF PLANT Dry Magnesium Sulfur Salts		SCOPE 100 TPD Sulfur	ESTIMATED BY JC		SHEET NO. 2 of 14

CODE	DESCRIPTION	MATERIAL	LABOR	SUBCONTR.	TOTAL $	MATERIAL	LABOR	SUBCONTR.$	TOTAL $	GRAND TOTAL $
A	FOUNDATIONS									
B	BUILDINGS									
C	STRUCTURAL STEEL									
	SUB-TOTAL STRUCT.(A-C)				190 000			280 000		
	SUB-TOTAL EQUIP.(D-R)				1 800 590			720 500		
S	INSULATION									
T	PIPING									
U	INSTRUMENTATION									
V	ELECTRICAL									
W	CHEMICALS & CATALYSTS									
X	PAINTING									
Y	MISC. SITE WORK									
Z	TRAVEL & SUBSISTENCE (LABOR)									
	SUB-TOTAL (S-Z)				433 600			625 000		
	TOTAL DIR. COSTS (A-Z)				2 424 190			1 993 000		
AA-AF	FIELD COSTS									
BA-BE	N.Y. OFFICE COSTS									
AG	START-UP SUPERVISION									
CC	START-UP M & L									
	SUB-TOTAL				2 679 190			2 043 000		
	TAXES & ROYALTIES									
	CONTINGENCY									
BC	CHEMICO OVERHEAD									
	TOTAL COST				3 197 690			2 145 000		
	FEES & PROFIT									
	SELLING PRICE				3 357 200			2 166 000		5 523 200

CHEMICO – COST ESTIMATE SUMMARY

CLIENT NAPCA	LOCATION CASE C	TYPE OF ESTIMATE Budget	ESTIMATE NO. 0067C	DATE 11/17/70
DESCRIPTION OF PLANT Calcination of $MgSO_3$ ONLY		SCOPE 100 TPD Sulfur	ESTIMATED BY JG	SHEET NO. 3 of 14

CODE	DESCRIPTION	MATERIAL	LABOR	SUBCONTR.	TOTAL $	MATERIAL	LABOR	SUBCONTR. $	TOTAL $	GRAND TOTAL $
A	FOUNDATIONS							40,000		
B	BUILDINGS							50,000		
C	STRUCTURAL STEEL				60,000					
	SUB-TOTAL STRUCT.(A-C)				60,000			90,000		
	Calciner Package				550,000					
	Baghouse				50,000					
	Waste Heat Boiler				50,500					
	Coke Storage Bin				6,900					
	Calciner Fan				Included					
	Duct Work				24,000					
	Screw Conveyor				2,100					
	Bucket Elevator				4,000					
	Screw Conveyor				6,300					
	SUB-TOTAL EQUIP.(D-R)				693,800			277,500		
S	INSULATION							37,500		
T	PIPING				100,000			120,000		
U	INSTRUMENTATION				25,000			35,000		
V	ELECTRICAL				30,000			120,000		
W	CHEMICALS & CATALYSTS									
X	PAINTING									
Y	MISC. SITE WORK									
Z	TRAVEL & SUBSISTENCE (LABOR)									
	SUB-TOTAL (S-Z)				155,000			312,500		
	TOTAL DIR. COSTS (A-Z)				908,800			680,000		
AA - AF	FIELD COSTS									
BA - BE	N.Y. OFFICE COSTS				70,000			25,000		
AG	START - UP SUPERVISION				P/D					
CC	START - UP M & L									
	N.Y.O. Expense				15,000					
	SUB-TOTAL				993,800			705,000		
	TAXES & ROYALTIES									
	CONTINGENCY 3% 5%				30,200					
BC	CHEMICO OVERHEAD				108,500			35,000		
	TOTAL COST				1,132,500			740,000		
	2 - 5 FEES & PROFIT				56,500			37,000		
	SELLING PRICE				1,189,000			777,000		1,966,000

Salaries:
10,000 @ 7.00 = 70,000

CHEMICAL CONSTRUCTION CORPORATION

SECTION CODE NO. ____ ESTIMATE JOB NO. D-9004 PAGE 4 OF 14

DESCRIPTION SO_2 Recovery REVISION NO. ____ DATE ____

LINE	CODE	DESCRIPTION OF ITEMS	QUANTITY	UNIT COSTS $		MAN-HOURS	ESTIMATED COST $				LINE
				MATERIAL	LABOR		MATERIAL	LABOR	SUBCONTR.	TOTAL	
1	D-202	Dryer Package	1								1
2		13' d x 105' L.C.		Fuller	Quote		450,000				2
3		Feed Conveyor									3
4		Fuel Pumps									4
5		Cyclone									5
6		Fan									6
7											7
8											8
9	D-203	Calciner Package	1	Fuller	Quote		550,000		CALCINATION		9
10		Fan									10
11		Fuel Oil Pump									11
12		Cyclone							CALCINATION		12
13		Fan (Off Gas)									13
14		Kiln Burner									14
15											15
16	D-206	Belt-Conveyor 60'	1				4,200				16
17		Bucket-Elevator 70'	1				7,000				17
18		850 CF/HR $MgSO_3$	1								18
19											19
20											20
21	D-205	Baghouse	1				50,000		CALCINATION		21
22											22
23											23
24											24
25											25
26	D-204	Waste Heat Boiler	1				50,500		CALCINATION		26
27											27
28											28
29											29
30											30
31											31
32	D-201	Stack	1				68,300				32
33		30' d - 50'									33
34		17' d - 100'									34
35		Wood Mist Elim.									35
36											36
37											37
38											38
					TOTAL		1,180,000				

CHEMICAL CONSTRUCTION CORPORATION

SECTION CODE NO. ______ ESTIMATE JOB NO. D-9004 PAGE 5 OF 14

DESCRIPTION SO_2 Recovery REVISION NO. ______ DATE ______

LINE	CODE	DESCRIPTION OF ITEMS	QUANTITY	UNIT COSTS $ MATERIAL	UNIT COSTS $ LABOR	MAN-HOURS	ESTIMATED COST $ MATERIAL	ESTIMATED COST $ LABOR	ESTIMATED COST $ SUBCONTR.	ESTIMATED COST $ TOTAL	LINE
1	I-209	Feed Conveyor	1	With Dryer			----				1
2	I-210-A	Belt Conveyor 35'	1				3,000				2
3	I-210-B	Bucket Elevator 50'	1				6,000				3
4	I-210-C	Weigh Feeder	1				2,000				4
5	I-210	Coke Storage Bin	1								5
6		8' d x 16' - 0"									6
7		with Bin Activator					6,900		CALCINATION		7
8											8
9											9
10	I-202	Storage Bin MgO	1								10
11		12'-0" d x 15'-0" CS									11
12		1 HP vib. Feeder					8,200				12
13											13
14											14
15	I-203-A	Bucket Elevator 60'					9,000				15
16	I-203-B	Screw Conveyor 30'					4,500				16
17	Make up MgO 10-90 CF/Hr. 25#/CF										17
18											18
19											19
20	I-204	MgO Dumping Hopper									20
21		10' d x 15' CS					1,800				21
22											22
23											23
24	I-206-A	Bucket Elevator 70'					6,500				24
25	I-206-B	Screw Conveyor 30'					3,000				25
26	I-206-C	Weigh Feeder					5,000				26
27		8-60 CF/Hr. 25#/CF									27
28											28
29											29
30	I-208-A	Screw Conveyor 60'					4,200				30
31	I-208-B	Screw Conveyor 30'					2,100				31
32		Baghouse to MgO Conveyor									32
33											33
34	I-209	Feed Conveyor		WITH DRYER			----				34
35											35
36											36
37	I-209	Coke Dumping Bin									37
38		6' d x 10'					900				38
					TOTAL		63,100				

CHEMICAL CONSTRUCTION CORPORATION

SECTION CODE NO. ______
ESTIMATE JOB NO. D-9004
PAGE 6 OF 14
DESCRIPTION SO_2 Recovery
REVISION NO. ______ DATE ______

LINE	CODE	DESCRIPTION OF ITEMS	QUANTITY	UNIT COSTS $		MAN-HOURS	ESTIMATED COST $				LINE
				MATERIAL	LABOR		MATERIAL	LABOR	SUBCONTR.	TOTAL	
1	J-201	Recycle Pumps & Motors	2								1
2		11,000 GPM - 175' MD									2
3		Alloy-20 BHP 325									3
4		400 HP Motors		6,000	EA.		12,000				4
5											5
6	J-202	Same as J-201	2	6,000	EA.		12,000				6
7		400 HP									7
8											8
9											9
10	J-203	Fuel Pump	2	With Dryer			----				10
11											11
12											12
13	J-204	Fuel Pump Oil	2	With Calciner			----				13
14											14
15											15
16											16
17	J-205	Slurry Pumps MgO	2								17
18		950 GPM- 225' MD									18
19		125 HP Motors		5,000	EA.		11,000				19
20											20
21											21
22											22
23											23
24											24
25											25
26											26
27											27
28											28
29											29
30											30
31											31
32											32
33											33
34											34
35											35
36											36
37											37
38											38
					TOTAL		35,000				

CHEMICAL CONSTRUCTION CORPORATION

SECTION CODE NO. ____________ ESTIMATE JOB NO. D-9004 PAGE 7 OF 14

DESCRIPTION SO_2 Recovery REVISION NO. ______ DATE ________

LINE	CODE	DESCRIPTION OF ITEMS	QUANTITY	UNIT COSTS $		MAN-HOURS	ESTIMATED COST $				LINE
				MATERIAL	LABOR		MATERIAL	LABOR	SUBCONTR.	TOTAL	
1	K-201	Fan									1
2		273,000 CFM 140° F 58"									2
3		BHP-3800 Motor 4000					165,000				3
4		Scrubber & Absorber									4
5											5
6											6
7	K-202	Fan - Dryer		With Package			-----				7
8		200 HP									8
9											9
10											10
11	K-205	Fan-Calciner		With Package			-----	CALCINATION			11
12		200 HP									12
13											13
14											14
15											15
16											16
17											17
18											18
19											19
20											20
21											21
22											22
23											23
24											24
25											25
26											26
27											27
28											28
29											29
30											30
31											31
32											32
33											33
34											34
35											35
36											36
37											37
38											38
					TOTAL		165,000				

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CHEMICAL CONSTRUCTION CORPORATION

SECTION CODE NO. ______

ESTIMATE JOB NO. D-9004

DESCRIPTION Scrubbing System

PAGE 8 OF 14

REVISION NO. ______ DATE ______

LINE	CODE	DESCRIPTION OF ITEMS	QUANTITY	UNIT COSTS $ MATERIAL	UNIT COSTS $ LABOR	MAN-HOURS	ESTIMATED COST $ MATERIAL	ESTIMATED COST $ LABOR	ESTIMATED COST $ SUBCONTR.	ESTIMATED COST $ TOTAL	LINE
1	G-601	Recycle Tank									1
2		16' d x 20' CS					48,000				2
3											3
4											4
5	G-602	Thick Overflow Tank									5
6		6'd x 4 CS RL									6
7							600				7
8											8
9	G-603	Slurry Tank									9
10		3' d x 3' CS									10
11							400				11
12											12
13											13
14	G-604	Neutralization Tank									14
15		5-Section 316 SS									15
16		5-Mixers 1 HP Ea.									16
17		1 1/2 x 3 x 8					7,200				17
18											18
19											19
20	G-201	MgO Slurry Tank									20
21		22' d, x 27' High CS					12,000				21
22											22
23											23
24											24
25											25
26											26
27											27
28											28
29											29
30											30
31											31
32											32
33											33
34											34
35											35
36											36
37											37
38											38
					TOTAL		68,200				

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CHEMICAL CONSTRUCTION CORPORATION

SECTION CODE NO. ________
DESCRIPTION Scrubbing System
ESTIMATE JOB NO. D-9004
PAGE 9 OF 14
REVISION NO. ______ DATE ______

LINE	CODE	DESCRIPTION OF ITEMS	QUANTITY	UNIT COSTS $		MAN-HOURS	ESTIMATED COST $				LINE
				MATERIAL	LABOR		MATERIAL	LABOR	SUBCONTR.	TOTAL	
1	I-601A	Storage Silo									1
2		25' d x 25' ST. Side					17,000				2
3											3
4											4
5											5
6											6
7	I-602	Lime Storage Bin									7
8		16' d x 23' CS									8
9		Bin Activator					8,400				9
10											10
11											11
12	I-603	Lime Slaker	1								12
13		BIF Co. #41-03					7,500				13
14											14
15											15
16											16
17	I-604A	Screw Lime Conveyor 20 ft.	1				1,400				17
18	B	Bucket Elevator 80 ft.	1				8,000				18
19	C	Weigh Feeder	1				1,500				19
20											20
21											21
22	I-605	Lime Dumping Hopper									22
23		10 x 10 x 20									23
24		2250 CF CS					5,400				24
25											25
26											26
27											27
28											28
29											29
30											30
31											31
32											32
33											33
34											34
35											35
36											36
37											37
38											38
					TOTAL		49,200				

CHEMICAL CONSTRUCTION CORPORATION

SECTION CODE NO. ______ ESTIMATE JOB NO. D-9004 PAGE 10 OF 14

DESCRIPTION Scrubbing System REVISION NO. ______ DATE ______

LINE	CODE	DESCRIPTION OF ITEMS	QUANTITY	UNIT COSTS $		MAN-HOURS	ESTIMATED COST $				LINE
				MATERIAL	LABOR		MATERIAL	LABOR	SUBCONTR.	TOTAL	
1	J-601	Recycle Pumps	2								1
2		180 GPM - 200 HP									2
3		Alloy 20 BHP - 15									3
4		20 HP - Motors					1,940				4
5		(Make-up Water)									5
6											6
7	J-602	Thick Underflow Pumps	2								7
8		30 GPM - 2-' HP									8
9		Alloy 20 2 HP Motors					500				9
10											10
11											11
12	J-603	Thick Overflow Pumps	2								12
13		135 GPM - 100 HP									13
14		Alloy 20 BHP - 5									14
15		7 1/2 HP - TEFC Motors					2,000				15
16											16
17											17
18	J-604	Recycle Pumps	2								18
19		4800 GPM - 100 'HP									19
20		Alloy 20 BHP-175									20
21		200 HP TEFC Motors					30,200				21
22		(Ash Scrubbers)									22
23											23
24	J-605	Slurry Pumps (Lime)	2								24
25		4 GPM - 20' HP									25
26		Alloy 20 1/2 HP					200				26
27											27
28	J-606	Neutral Sol. Pumps	2								28
29		30 GPM-30' HP									29
30		Alloy 20 BHP - 1.5									30
31		2 HP Motors					400				31
32											32
33											33
34											34
35											35
36											36
37											37
38											38
					TOTAL		35,240				

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CHEMICAL CONSTRUCTION CORPORATION

SECTION CODE NO. ______ ESTIMATE JOB NO. D-9004 PAGE 11 OF 14

DESCRIPTION Scrubbing System REVISION NO. ______ DATE ______

LINE	CODE	DESCRIPTION OF ITEMS	QUANTITY	UNIT COSTS $ MATERIAL	UNIT COSTS $ LABOR	MAN-HOURS	ESTIMATED COST $ MATERIAL	ESTIMATED COST $ LABOR	ESTIMATED COST $ SUBCONTR.	ESTIMATED COST $ TOTAL	LINE
1	R-601	Centrifuge	1								1
2		24 x 60 316 SS									2
3		BHP - 90 100 HP Motor					38,500				3
4											4
5											5
6	R-602	Thickeners	2								6
7	A & B	30 ft. dia. CS RL									7
8		Fly Ash - FE 203		11,000	each		22,000				8
9											9
10											10
11	R-604	Scrubber (Ash & Acid Mist)	1								11
12		326,000 ACFM									12
13		26' d x 40					118,600				13
14											14
15											15
16											16
17											17
18											18
19											19
20											20
21	R-201	Absorber									21
22		261,000 ACFM									22
23		30' d x 90'					187,000				23
24											24
25											25
26	R-202	Centrifuges	4								26
27		250 HP									27
28		36 x 96 Bird Co.		75,000	Each		300,000				28
29											29
30											30
31											31
32	R-203	Cyclone		With Dryer			-----				32
33											33
34											34
35	R-204	Cyclone		With Calciner			-----				35
36											36
37											37
38											38
					TOTAL		666,100				

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CHEMICAL CONSTRUCTION CORPORATION

SECTION CODE NO. ____ ESTIMATE JOB NO. D-9004 PAGE 12 OF 14

DESCRIPTION ____ REVISION NO. ____ DATE ____

LINE	CODE	DESCRIPTION OF ITEMS	QUANTITY	UNIT COSTS		MAN-HOURS	ESTIMATED COST				LINE
				MATERIAL	LABOR		MATERIAL	LABOR	SUBCONTR.	TOTAL	
1		Duct Work									1
2											2
3		From Cyclone 11'-6' d 1/2 CSH	160'								3
4		Duct 420 x 160	67,200#	35/			23,500				4
5		Stiffeners		Allow			3,500				5
6		Ceilcote	5,700SF	1-			5,700		17,100		6
7											7
8											8
9											9
10		Absorber To Stack									10
11		11'-6" x 1/4" CSH	85'								11
12		Duct 420 x 85	35,700#	35/			12,500				12
13		Stiffeners		Allow			[illegible],900				13
14		Ceilcote	3,000SF	1-			3,000		9,000		14
15											15
16											16
17		Dryer to Stack									17
18		7' ϕ 1/4" CS 1ϕ	260'								18
19		Duct 2 260	66,560#	35/			23,300				19
20		Stiff.		Allow			3,500				20
21											21
22											22
23		Calciner to Waste Heat Boiler									23
24		4'-6" ϕ	70'								24
25		Duct 165 x 70	11,550	35/			4,100		CALCINATION		25
26		Stiff		Allow			600		"		26
27		Castable Lining	980 SF						5,000		27
28											28
29											29
30		Waste Heat Boiler to Baghouse									30
31		3'-0" ϕ	4,351								31
32		Duct 110 x 430	71,850	35/			16,750		CALCINATION		32
33		Stiff		Allow			2,500		"		33
34											34
35											35
36											36
37											37
38											38
					TOTAL		100,850		31,100	131,950	

CHEMICAL CONSTRUCTION CORPORATION

SECTION CODE NO. ______ ESTIMATE JOB NO. D-9004 PAGE 13 OF 14

DESCRIPTION ______ REVISION NO. ______ DATE ______

LINE	CODE	DESCRIPTION OF ITEMS	QUANTITY	UNIT COSTS $ MATERIAL	UNIT COSTS $ LABOR	MAN-HOURS	ESTIMATED COST $ MATERIAL	ESTIMATED COST $ LABOR	ESTIMATED COST $ SUBCONTR.	ESTIMATED COST $ TOTAL	LINE
1		Duct Work									1
2											2
3											3
4		Duct From Claus									4
5		5' d x 1/4' CSH	320'								5
6		Duct 183 x 320	58,560"	35/			20,500				6
7		Stiff.		Allow			3,500				7
8											8
9											9
10											10
11		Boiler To Baghouse To Fan									11
12		3' d 1/4 CSH	435'								12
13		Duct 110 x 435	47,850	35/			16,750				13
14		Stiff.		Allow			2,550				14
15											15
16											16
17											17
18		Scrubber To Stack									18
19		11' d x 1/4" CSH	150'								19
20		Duct 402 x 150	60,300#	35/			21,100				20
21		Stiff.		Allow			3,100				21
22		Ceilcote Lining	5,200SF	1-			5,200		15,600		22
23											23
24											24
25											25
26											26
27											27
28											28
29											29
30											30
31											31
32											32
33											33
34											34
35											35
36											36
37											37
38											38
				TOTAL			72,700		15,600	88,300	

CHEMICAL CONSTRUCTION CORPORATION

SECTION CODE NO. ______

DESCRIPTION ______

ESTIMATE JOB NO. D-9004

PAGE 14 OF 14

REVISION NO. ______ DATE ______

LINE	CODE	DESCRIPTION OF ITEMS	QUANTITY	UNIT COSTS $		MAN-HOURS	ESTIMATED COST $				LINE
				MATERIAL	LABOR		MATERIAL	LABOR	SUBCONTR.	TOTAL	
1		Dampers									1
2											2
3											3
4		No Specs		Allow			36,500				4
5											5
6											6
7											7
8											8
9											9
10		Expansion Joints									10
11											11
12		No Specs		Allow			22,500				12
13											13
14											14
15											15
16											16
17											17
18											18
19											19
20											20
21											21
22											22
23											23
24											24
25											25
26											26
27											27
28											28
29											29
30											30
31											31
32											32
33											33
34											34
35											35
36											36
37											37
38											38
					TOTAL		59,000				

CHEMICO – COST ESTIMATE SUMMARY

CLIENT NAPCA

LOCATION Midwest, U.S.A.

TYPE OF ESTIMATE Budget

ESTIMATE NO. 0067C

DATE

DESCRIPTION OF PLANT 100 TPD Sulfur from 15% SO2 Case C

SCOPE Erected

ESTIMATED BY JRB

SHEET NO. 1 of 10

CODE	DESCRIPTION	MATERIAL	LABOR	SUBCONTR.	TOTAL	MATERIAL	LABOR	SUBCONTR.	TOTAL	GRAND TOTAL
A	FOUNDATIONS			25,000						
B	BUILDINGS	19,000		88,000						
C	STRUCTURAL STEEL			50,000						
	SUB-TOTAL STRUCT.(A-C)	19,000		233,000						
D	Boilers & Heaters	331,000								
E	Heat Exchangers	312,100								
G	Tanks & Vessels	37,000								
H	Reactors	27,100		62,600						
J	Pumps	23,200								
K	Compressors	422,000								
R	Special Equipt.	22,000								
	SUB-TOTAL EQUIP.(D-R)	1,174,400		62,600						
S	INSULATION			75,000						
T	PIPING	190,000								
U	INSTRUMENTATION	90,000								
V	ELECTRICAL	20,000		60,000						
W	CHEMICALS & CATALYSTS	52,000								
X	PAINTING			15,000						
Y	MISC. SITE WORK									
Z	TRAVEL & SUBSISTENCE (LABOR)									
	SUB-TOTAL (S-Z)	352,000		150,000						
	TOTAL DIR. COSTS (A-Z)	1,545,400	269,000	445,600	2,260,000					
		AA - AF	FIELD COSTS .60 x F.L.		160,000					
		BA - BE	N.Y. OFFICE COSTS		210,000					
		AG	START - UP SUPERVISION							
		CC	START - UP M & L		50,000					
				SUB-TOTAL	2,680,000					
			TAXES & ROYALTIES							
			CONTINGENCY		300,000					
		BC	CHEMICO OVERHEAD		250,000					
				TOTAL COST	3,230,000					
				FEES & PROFIT	170,000					
				SELLING PRICE	3,400,000					

CHEMICAL CONSTRUCTION CORPORATION

SECTION CODE NO. A, B, C
ESTIMATE JOB NO. 0067C
PAGE 2 OF 10
DESCRIPTION Sulfur Recovery from 15% SO_2
REVISION NO. ______ DATE ______

LINE	CODE	DESCRIPTION OF ITEMS	QUANTITY	UNIT COSTS		MAN-HOURS	ESTIMATED COST				LINE
				MATERIAL	LABOR		MATERIAL	LABOR	SUBCONTR.	TOTAL	
1	A	Foundations							90,000		1
2		Crushed Stone paving							2,000		2
3		Asphalt Paving							3,000		3
4											4
5	B	Control Building & MCC	1						20,000		5
6		20' x 30' x 12'H and									6
7		10' x 12' x 12'H									7
8		Masonry Construction									8
9											9
10	B	Compressor Building	1						68,000		10
11		45' x 10' x 43' eave Ht									11
12		with elevated Steel									12
13		operating floor									13
14		steel frame, corr. Asb.									14
15		roof & siding									15
16											16
17		Bridge crane	1				19,000				17
18		35 ton, 50' span									18
19		All electric drives									19
20											20
21	C	Structural steel							50,000		21
22											22
23											23
24											24
25											25
26											26
27											27
28											28
29											29
30											30
31											31
32											32
33											33
34											34
35											35
36											36
37											37
38											38
					TOTAL		19 000		233 000	25 200	

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CHEMICAL CONSTRUCTION CORPORATION

SECTION CODE NO. D
DESCRIPTION Sulfur Recovery from 15% SO2
ESTIMATE JOB NO. 0067C
PAGE 3 OF 10
REVISION NO. ______ DATE ______

LINE	CODE	DESCRIPTION OF ITEMS	QUANTITY	UNIT COSTS		MAN-HOURS	ESTIMATED COST				LINE
				MATERIAL	LABOR		MATERIAL	LABOR	SUBCONTR.	TOTAL	
1	D-101	Standby boiler	1				$60,000				1
2		32,000 #/H 515 PSI 675°F									2
3		Incl. superheater									3
4		economizer									4
5		F.D. fan & motor									5
6		Stack									6
7											7
8	D-601	Incinerator	1				21,000				8
9		1 ø x 1 Lg. Horiz.									9
10		N.G. fired									10
11											11
12	D-201	Autothermal reformer	1				250,000				12
13		Package Unit									13
14											14
15											15
16											16
17											17
18											18
19											19
20											20
21											21
22											22
23											23
24											24
25											25
26											26
27											27
28											28
29											29
30											30
31											31
32											32
33											33
34											34
35											35
36											36
37											37
38											38
					TOTAL		$331,000				

CHEMICAL CONSTRUCTION CORPORATION

SECTION CODE NO. E
DESCRIPTION Sulfur & Recovery from 15% SO_2
ESTIMATE JOB NO. 0067C
PAGE 4 OF 10
REVISION NO. ______ DATE ______

LINE	CODE	DESCRIPTION OF ITEMS	QUANTITY	UNIT COSTS		MAN-HOURS	ESTIMATED COST				LINE
				MATERIAL	LABOR		MATERIAL	LABOR	SUBCONTR.	TOTAL	
1	E-103	Gas Cooler	1				$ 12,800				1
2		All C.S. 2845 SF									2
3		44" Ø x 156"									3
4		Tubes 1¼" x 13'									4
5											5
6	E-104	Hot Water Cooler	1				3,000				6
7		All C.S. 267 SF									7
8											8
9	E-201	Reduction W.H. Boiler	1				42,000				9
10		22,600 #/hr 550psig Sat.									10
11											11
12	E-301	Steam Condenser	1				35,000				12
13		C.S. with ADM Tubes									13
14		2690 SF									14
15											15
16	E-501	Claus Boiler	1				16,300				16
17		Type CKN 930 SF									17
18		Tubes 2" x 11 Bwg x 7'									18
19		347 SS									19
20		TS & Chan 347 clap									20
21		Shell C.S.									21
22											22
23	E-502	Claus Reactor Reheater	1				43,000				23
24		Type CEN 4315 SF									24
25		All C.S									25
26		Tubes 2" x 11 BWG x 20'-10"									26
27											27
28	E-503	First Claus Condenser	1				33,000				28
29		Type CEM 5105 SF									29
30		All C.S. Tubes 2"x11BWGx24'									30
31											31
32	E-504	Second Claus Condenser	1				35,000				32
33		Type CEN 5473 SF									33
34		All C.S. Tubes 2"x11BWGx26'									34
35											35
36	E-601	Incinerator Preheater	1				92,000				36
37		Type CEN 8884 SF									37
38		Tubes 1½" x 14GA x 30' 347SS									38
		TS Chan & Shell 304 or refract. Clad.			TOTAL		$312,100				

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CHEMICAL CONSTRUCTION CORPORATION

SECTION CODE NO. G
ESTIMATE JOB NO. 0067C
PAGE 5 OF 10
DESCRIPTION Sulfur Recovery from 15% SO_2
REVISION NO. ______ DATE ______

LINE	CODE	DESCRIPTION OF ITEMS	QUANTITY	UNIT COSTS		MAN-HOURS	ESTIMATED COST				LINE
				MATERIAL	LABOR		MATERIAL	LABOR	SUBCONTR.	TOTAL	
1	G-101	Hot water surge tank	1				$ 3,600				1
2		7'Ø x 12' vertical C.S.									2
3		Atm. Tank	6060#								3
4											4
5	G-102	Inert Gas Receivers	2				13,000				5
6		3'Ø x 13' vert C.S.									6
7		DP 150 PSIG	13,000# ea.								7
8											8
9	G-103	L.P. WHB Blowdown tank	1				1,300				9
10		2' Ø x 5' vertical C.S.									10
11		DP 25 PSIG	1670								11
12											12
13	G-104	H.P. WHB Blowdown Tank	2				2,200				13
14		2' Ø x 3'-6" vertical C.S.									14
15		DP 160 PSIG	1460# ea.								15
16											16
17	G-301	Deagrator	1				7,100				17
18		Spray tray type									18
19		79,000 #/hr. capacity									19
20											20
21	G-501	Claus Separator	1				5,300				21
22		6'-6" ID x 41'3" vert.C.S.	10,000#								22
23		Mist Pad 316SS	2				1,200				23
24		Steam Coils, C.S.	1 set				1,800				24
25		Internal piping	11 set				500				25
26		Grating	1 set				400				26
27											27
28	G-302	Steam Vent Silencer	1				600				28
29		Vertical, C.S.									29
30		50,000 #/Hr. Capacity									30
31											31
32											32
33											33
34											34
35											35
36											36
37											37
38											38
					TOTAL		$37,000				

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CHEMICAL CONSTRUCTION CORPORATION

SECTION CODE NO. H
ESTIMATE JOB NO. 0067C
PAGE 6 OF 10
DESCRIPTION Sulfur Recovery from 15% SO_2
REVISION NO. ______ DATE ______

LINE	CODE	DESCRIPTION OF ITEMS	QUANTITY	UNIT COSTS		MAN-HOURS	ESTIMATED COST				LINE
				MATERIAL	LABOR		MATERIAL	LABOR	SUBCONTR.	TOTAL	
1	H-201	Reduction Reactor	1								1
2		11'Ø x 15' vert. C.S.									2
3		DP 36 PSIG	19,600#				$ 8,900				3
4		Checker Brickwork					1,500				4
5		Refractory Lining					2,600				5
6		Gravel Packing					500				6
7		Catalyst					with "W"				7
8											8
9	H-501	Claus Reactor	1						$43,000		9
10		21' Ø x 40'-7" Vert. C.S.									10
11		DP 15 PSIG	89,300#								11
12		Refractory Lining					6,000		17,300		12
13		Firebrick Packing					5,700				13
14		Grating					2,400		5,300		14
15											15
16											16
17											17
18											18
19											19
20											20
21											21
22											22
23											23
24											24
25											25
26											26
27											27
28											28
29											29
30											30
31											31
32											32
33											33
34											34
35											35
36											36
37											37
38											38
					TOTAL		$27,100		$62,600	89,700	

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CHEMICAL CONSTRUCTION CORPORATION

SECTION CODE NO. J
ESTIMATE JOB NO. 0067C
PAGE 7 OF 10
DESCRIPTION Sulfur Recovery from 15% SO_2
REVISION NO. ______ DATE ______

LINE	CODE	DESCRIPTION OF ITEMS	QUANTITY	UNIT COSTS		MAN-HOURS	ESTIMATED COST				LINE
				MATERIAL	LABOR		MATERIAL	LABOR	SUBCONTR.	TOTAL	
1	J-101	Hot Water Recirc. Pumps	2				$ 1,000				1
2		C.I. Centrifugal									2
3		200 GPM 0-50 PSIG									3
4		Motor 5HP	2				INCL				4
5											5
6	J-102	Boiler Feedwater Pumps	2				17,000				6
7		C.I. Multi Stage Centr.									7
8		170 GPM 0-700 PSIG									8
9		Motor									9
10		Turbine 500 85PSI									10
11											11
12	J-301	Condensate Return Pumps	2				1,000				12
13		C. I. Centrifugal									13
14		110 GPM 0-45 PSIG									14
15		Motor 5HP	2				Incl.				15
16											16
17	J-501	Sulfur Pumps	2				4,200				17
18		C.I. Centrifugal with									18
19		Steam Jacket									19
20		40 GPM 22'TON									20
21		Motor, 1 HP	2				Incl.				21
22											22
23											23
24											24
25											25
26											26
27											27
28											28
29											29
30											30
31											31
32											32
33											33
34											34
35											35
36											36
37											37
38											38
					TOTAL		$23,200				

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CHEMICAL CONSTRUCTION CORPORATION

SECTION CODE NO. K
ESTIMATE JOB NO. 0067C
PAGE 8 OF 10
DESCRIPTION Sulfur Recovery from 15% SO_2
REVISION NO. ____ DATE ____

LINE	CODE	DESCRIPTION OF ITEMS	QUANTITY	UNIT COSTS		MAN-HOURS	ESTIMATED COST				LINE
				MATERIAL	LABOR		MATERIAL	LABOR	SUBCONTR.	TOTAL	
1	K-206	Feed Gas Compressor	1				$235,000				1
2		Centrifugal, C.I.									2
3		17,800 SCFM, 12-40 PSIA									3
4		with accessories									4
5		2586 HP Turbine	1				Incl.				5
6		500 PSI - 4.5" Hg.									6
7											7
8	K-207	Air Compressor	1				170,000				8
9		Centrifugal, C.I.									9
10		5,076 SCFM 0-80 PSIG									10
11		with accessories									11
12		1225 HP Turbine	1				Incl.				12
13		500 PSI - 4.5" Hg.									13
14											14
15	K-601	Incinerator Air Blower	1				7,000				15
16		Centrifugal									16
17		5180 SCFM, 0-75" Hg.									17
18		125 HP Motor									18
19											19
20	K-101	Start up Vent Blower	1				10,000				20
21		Centrifugal									21
22		28,000 SCFM 14.Z - 14.7 PSIA									22
23		Motor 100 HP	1				Incl.				23
24											24
25											25
26											26
27											27
28											28
29											29
30											30
31											31
32											32
33											33
34											34
35											35
36											36
37											37
38											38
					TOTAL		$422,000				

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CHEMICAL CONSTRUCTION CORPORATION

SECTION CODE NO. R
ESTIMATE JOB NO. 0067C
PAGE 9 OF 10
DESCRIPTION Sulfur Recovery from 15% SO_2
REVISION NO. ______ DATE ______

LINE	CODE	DESCRIPTION OF ITEMS	QUANTITY	UNIT COSTS MATERIAL	UNIT COSTS LABOR	MAN-HOURS	ESTIMATED COST MATERIAL	ESTIMATED COST LABOR	ESTIMATED COST SUBCONTR.	ESTIMATED COST TOTAL	LINE
1	R-101	Phosphate Feed System, HP.	2				$ 1,000				1
2		0-2 GPM pump 0-625 Psi									2
3		32 gal. tank									3
4											4
5	R-102	Phosphate Feed System L.R.	1				500				5
6		0-2 GPM pump, 0-150 Psi									6
7		32 Gal. tank									7
8											8
9	R-103	Hydrazine Feed System	1				500				9
10		0.2 GPM pump 0-50 Psi									10
11		16 gal. tank									11
12											12
13	R-104	Inert Gas Generator	1				20,000				13
14		Skip mounted package									14
15		Unit, 3000 SCFH capacity									15
16		Delivered at 100 PSIG									16
17											17
18											18
19											19
20											20
21											21
22											22
23											23
24											24
25											25
26											26
27											27
28											28
29											29
30											30
31											31
32											32
33											33
34											34
35											35
36											36
37											37
38											38
					TOTAL		$22,000				

CHEMICAL CONSTRUCTION CORPORATION

SECTION CODE NO. S.T.U.V.W.X.
DESCRIPTION Sulfur Recovery from 15% SO_2
ESTIMATE JOB NO. 0067C
PAGE 10 OF 10
REVISION NO. ______ DATE ______

LINE	CODE	DESCRIPTION OF ITEMS	QUANTITY	UNIT COSTS		MAN-HOURS	ESTIMATED COST				LINE
				MATERIAL	LABOR		MATERIAL	LABOR	SUBCONTR.	TOTAL	
1	S	Insulation - Equipt.							$30,000		1
2		- Piping							45,000		2
3											3
4	T	Piping					$190,000				4
5											5
6											6
7											7
8											8
9											9
10											10
11	U	Instruments					90,000				11
12											12
13											13
14											14
15											15
16	V	Electrical 19M					20,000		60,000		16
17											17
18											18
19											19
20	W	Catalyst					52,000				20
21											21
22											22
23											23
24											24
25											25
26											26
27											27
28	X	Painting							15,000		28
29											29
30											30
31											31
32											32
33											33
34											34
35											35
36											36
37											37
38											38
		TOTAL					352,000		150,000	502,000	

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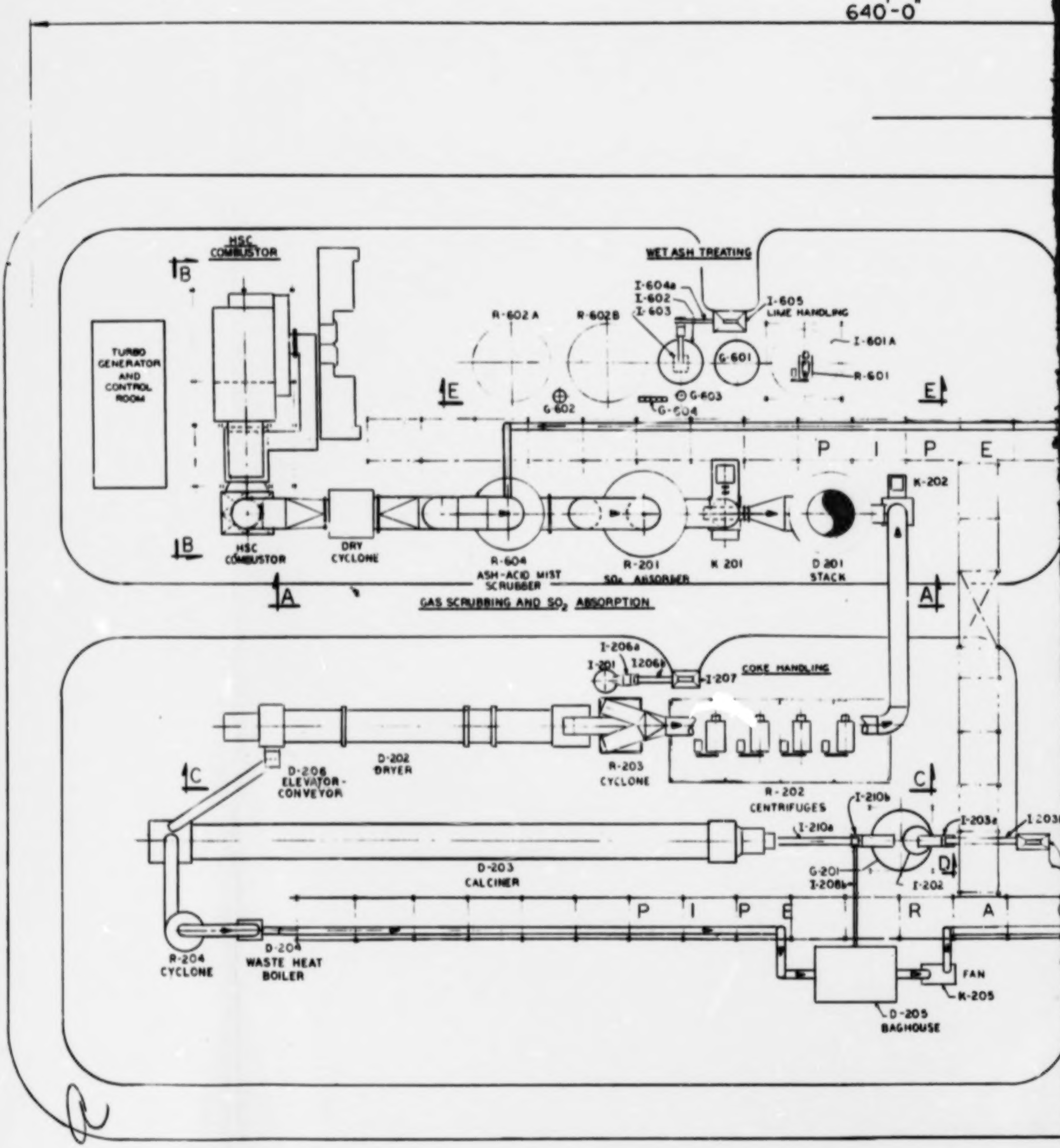
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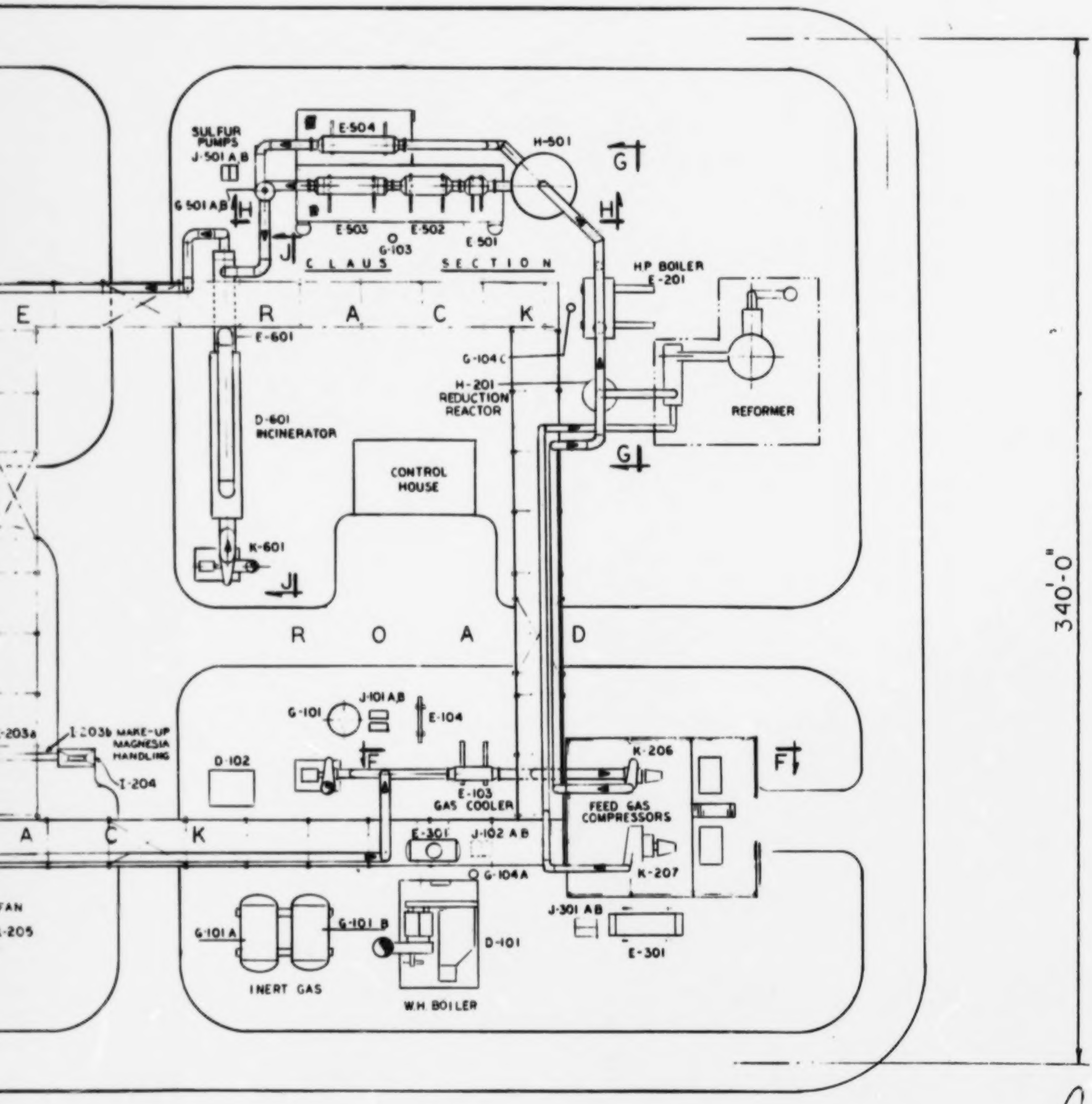
HSC COMBUSTOR
TURBO GENERATOR AND CONTROL ROOM
B
B
WET ASH TREATING
I-604a
I-602
I-603
I-605
LIME HANDLING
R-602 A
R-602 B
G-601
I-601A
R-601
E
E
G-602
G-603
G-604
P I P E
K-202
HSC COMBUSTOR
DRY CYCLONE
R-604
ASH-ACID MIST SCRUBBER
R-201
SO₂ ABSORBER
K 201
D 201
STACK
A
A
GAS SCRUBBING AND SO₂ ABSORPTION
I-206a
I-201
I206b
I-207
COKE HANDLING
D-202
DRYER
R-203
CYCLONE
C
C
D-206
ELEVATOR-CONVEYOR
R-202
CENTRIFUGES
I-210b
I-210a
I-203a
I-203b
D-203
CALCINER
G-201
I-208b
D
I-202
P I P E R A
R-204
CYCLONE
D-204
WASTE HEAT BOILER
FAN
K-205
D-205
BAGHOUSE

HIGH SULFUR COMBUSTOR STUDY

CASE C PROTOTYPE

BATTERY LIMITS PLAN


SULFUR PUMPS
J-501 A,B
E-504
H-501
G 501 A,B
E 503
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E 501
G-103
CLAUS SECTION
HP BOILER E-201
E R A C K
E-601
G-104 C
H-201 REDUCTION REACTOR
REFORMER
D-601 INCINERATOR
CONTROL HOUSE
K-601
R O A D
G-101
J-101 A,B
E-104
I-203a
I-203b MAKE-UP MAGNESIA HANDLING
I-204
D-102
E-103 GAS COOLER
K-206
FEED GAS COMPRESSORS
K-207
A C K
E-301
J-102 A B
G-104A
FAN
-205
G-101 A
G-101 B
D-101
INERT GAS
W.H BOILER
J-301 A B
E-301
G
H
J
F
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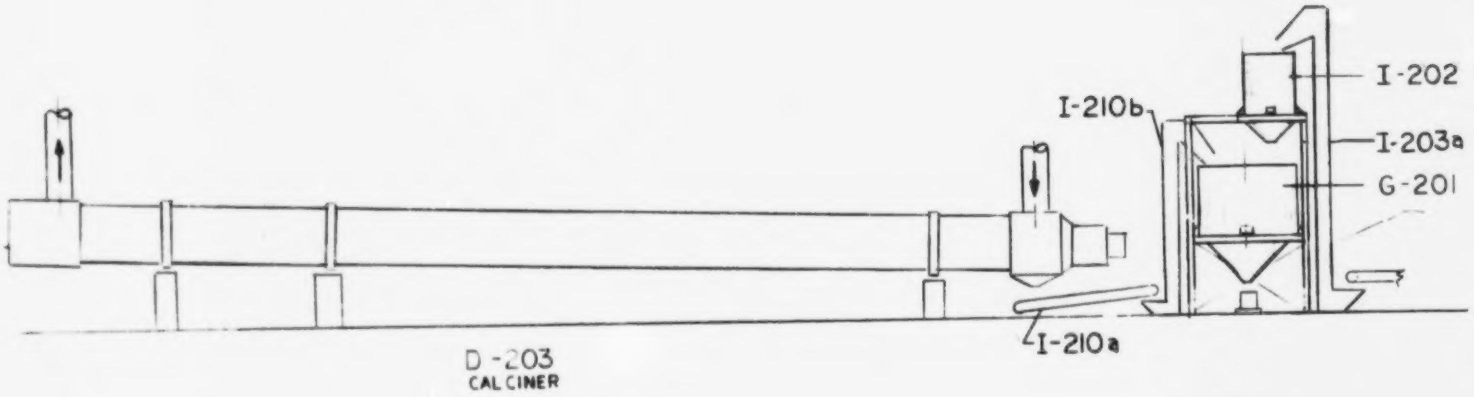
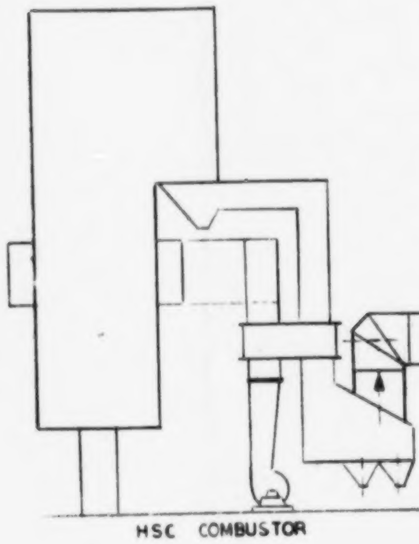
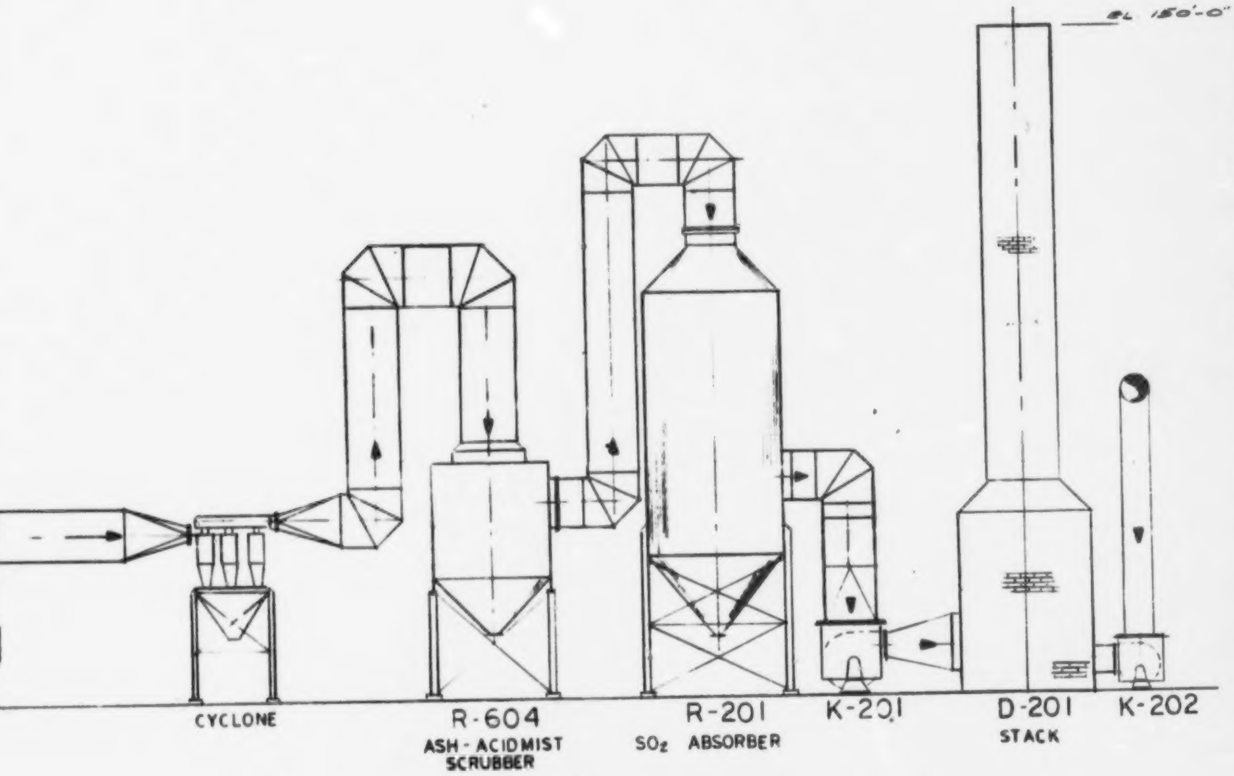

I-202
I-210b
I-203a
G-201
I-210a
D-203
CALCINER

SECTION D - D

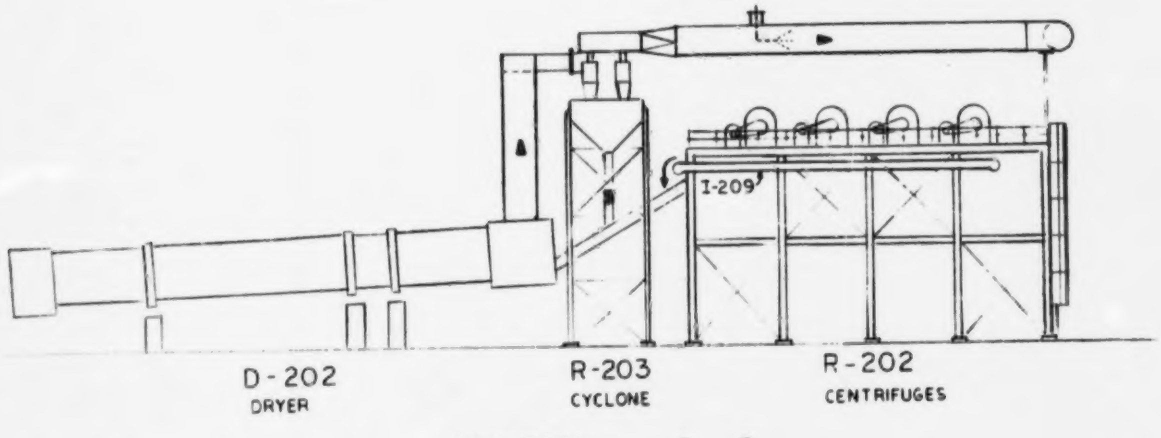

HSC COMBUSTOR

SECTION B - B


EL 150'-0"
CYCLONE
R-604
ASH-ACIDMIST SCRUBBER
R-201
SO₂ ABSORBER
K-201
D-201
STACK
K-202

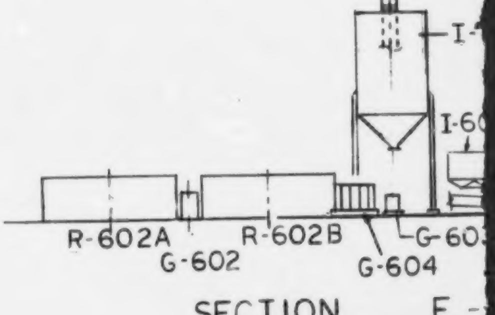
SECTION A-A

GAS SCRUBBING AND SO_2 ABSORPTION


I-209
D-202
DRYER
R-203
CYCLONE
R-202
CENTRIFUGES

SECTION C - C

MAGNESIUM SALTS DEHYDRATION


R-602A
G-602
R-602B
G-604
G-60

SECTION E -

WET ASH TREATING

a

HIGH SULFUR COMBUSTOR STUDY

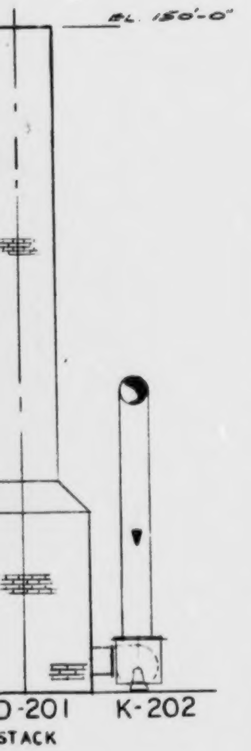
CASE C PROTOTYPE

BATTERY LIMITS ELEVATIONS

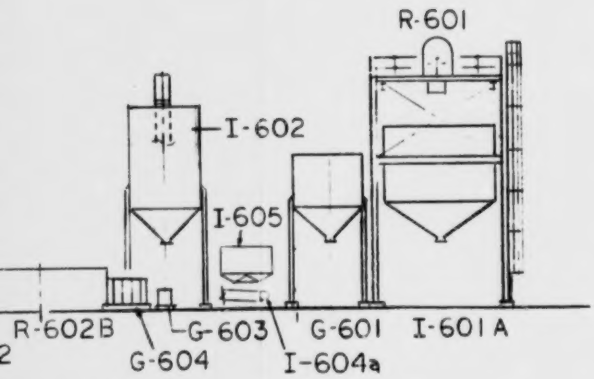
02

3a

01



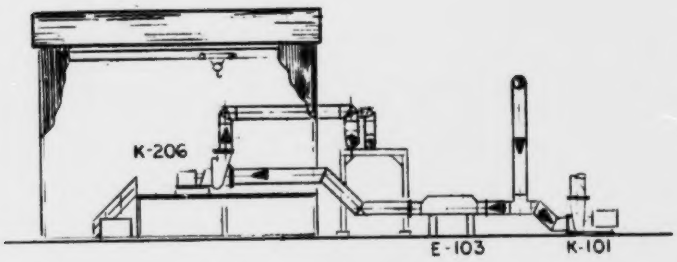
EL. 150'-0"
D-201
K-202
STACK



R-601
I-602
I-605
R-602B
G-604
G-603
G-601
I-601A
I-604a
2

ECTION E - E

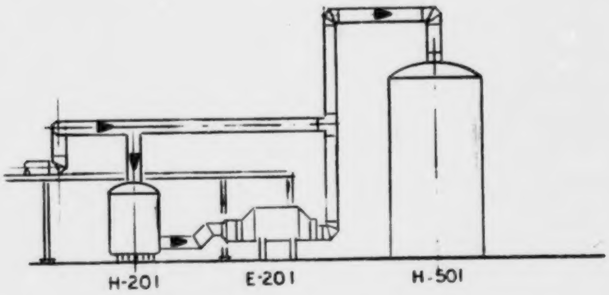
WET ASH TREATING



K-206
E-103
K-101

SECTION F - F

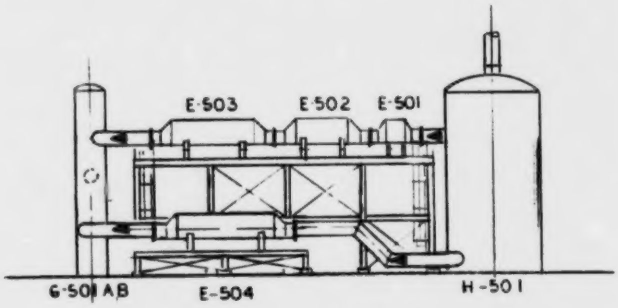
COMPRESSION



H-201
E-201
H-501

SECTION G - G

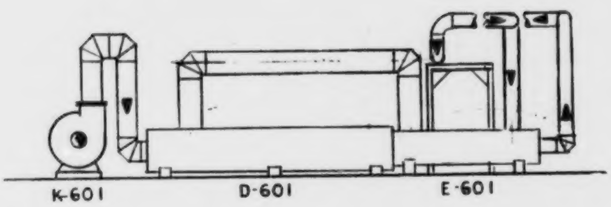
SO_2 REDUCTION



E-503
E-502
E-501
G-501 AB
E-504
H-501

SECTION H - H

CLAUS PLANT

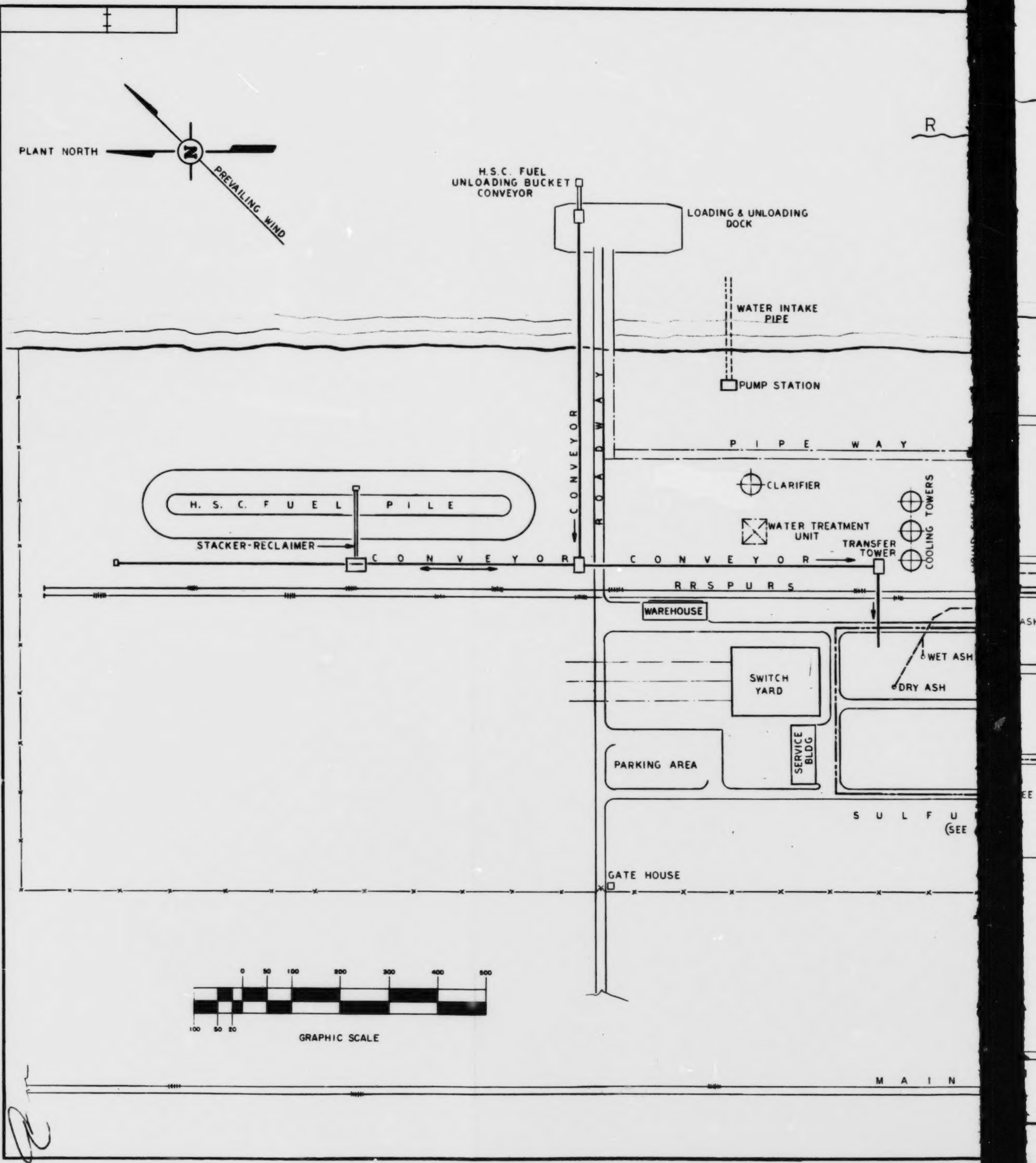


K-601
D-601
E-601

SECTION J - J

INCINERATOR

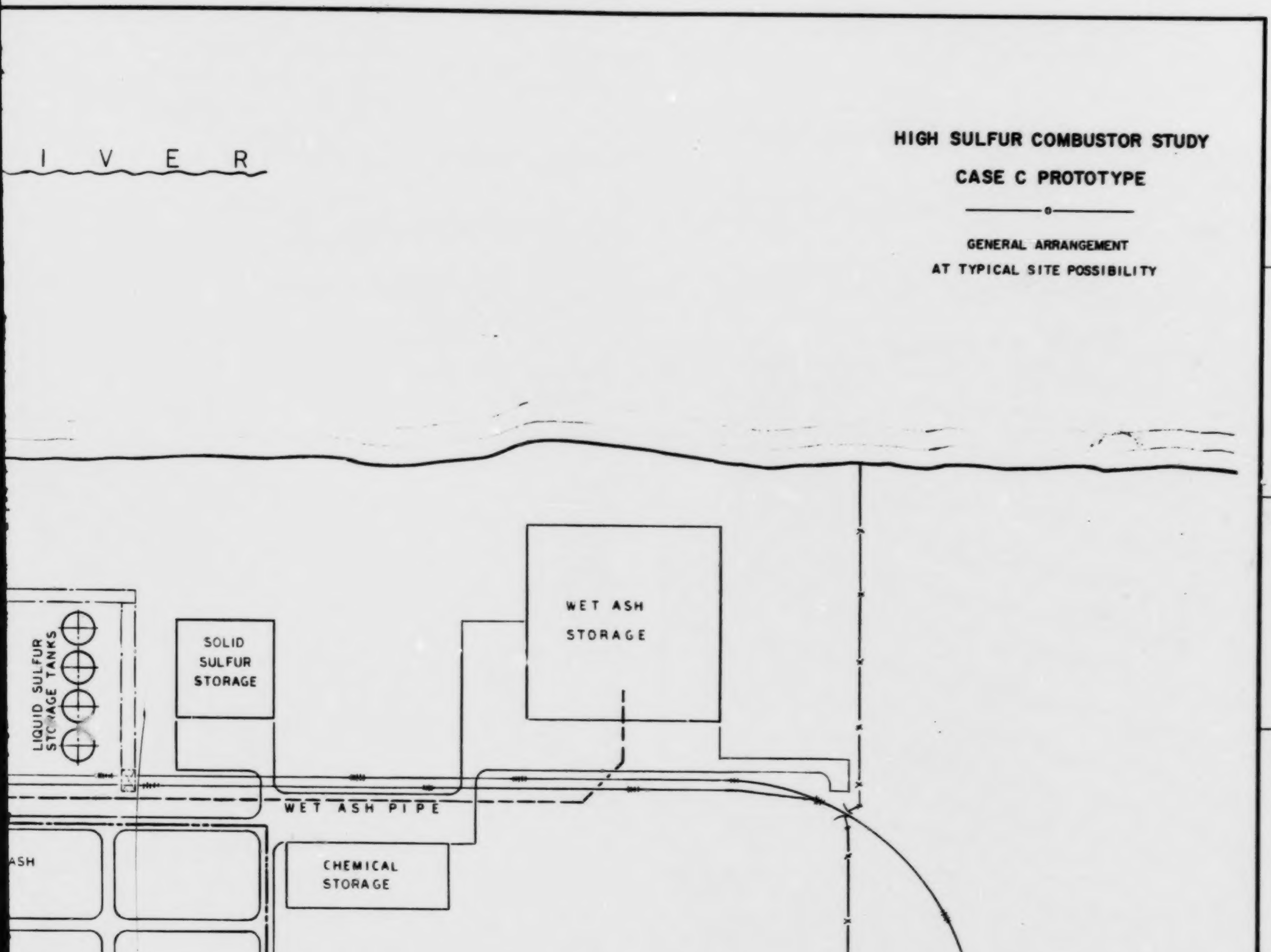
B


PLANT NORTH
N
PREVAILING WIND
H.S.C. FUEL UNLOADING BUCKET CONVEYOR
LOADING & UNLOADING DOCK
WATER INTAKE PIPE
PUMP STATION
CONVEYOR
ROADWAY
PIPE WAY
CLARIFIER
WATER TREATMENT UNIT
COOLING TOWERS
TRANSFER TOWER
H. S. C. FUEL PILE
STACKER-RECLAIMER
CONVEYOR
CONVEYOR
RR SPURS
WAREHOUSE
SWITCH YARD
WET ASH
DRY ASH
ASH
SERVICE BLDG
PARKING AREA
SULFU
(SEE
EE
GATE HOUSE
0 50 100 200 300 400 500
100 50 20
GRAPHIC SCALE
MAIN
R

HIGH SULFUR COMBUSTOR STUDY

CASE C PROTOTYPE

GENERAL ARRANGEMENT
AT TYPICAL SITE POSSIBILITY


I V E R
LIQUID SULFUR STORAGE TANKS
SOLID SULFUR STORAGE
WET ASH STORAGE
WET ASH PIPE
ASH
CHEMICAL STORAGE
R PLANT
EE FIG. NO.)
PROPERTY FENCE
RR LINE
G
F
E
D
C
B

CASE C
PROTOTYPE

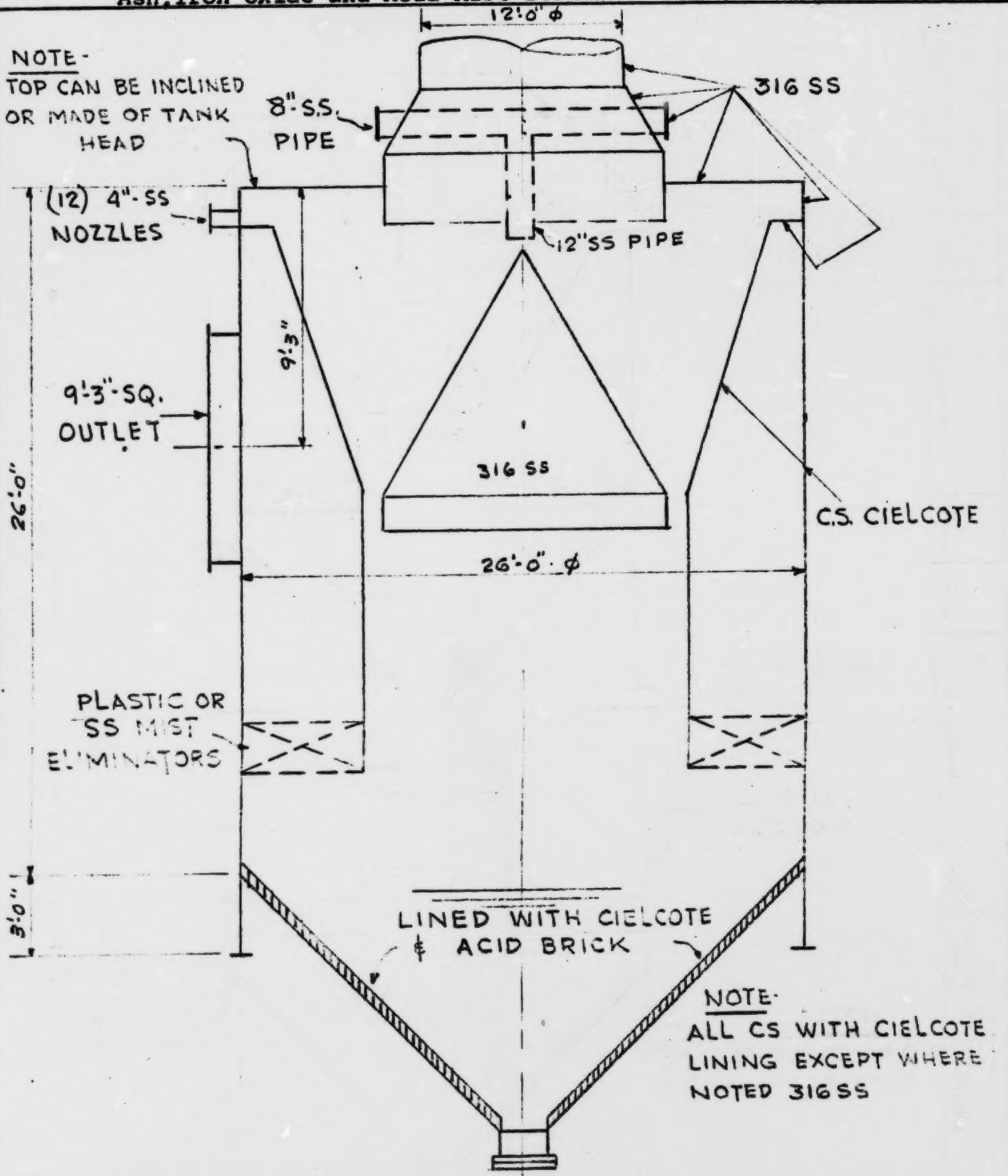
Equipment List And Specifications

FLUE GAS CLEANING
SULFUR DIOXIDE ABSORPTION
MAGNESIUM SALTS DRYING
MAGNESIUM SALTS CALCINATION

CLIENT AND LOCATION
High Sulfur Combustor Study

PLANT SECTION NAME AND SECTION NUMBER
Intermediate Chemical Product -S° 100 T/D

Ash, Iron Oxide and Acid Mist Scrubber


12'-0" ϕ
316 SS
8" S.S. PIPE
(12) 4"-SS NOZZLES
12" SS PIPE
9'-3"
9'-3"-SQ. OUTLET
26'-0"
316 SS
C.S. CIELCOTE
26'-0" ϕ
PLASTIC OR SS MIST ELIMINATORS
3'-0"
LINED WITH CIELCOTE & ACID BRICK

NOTE - TOP CAN BE INCLINED OR MADE OF TANK HEAD

NOTE - ALL CS WITH CIELCOTE LINING EXCEPT WHERE NOTED 316 SS

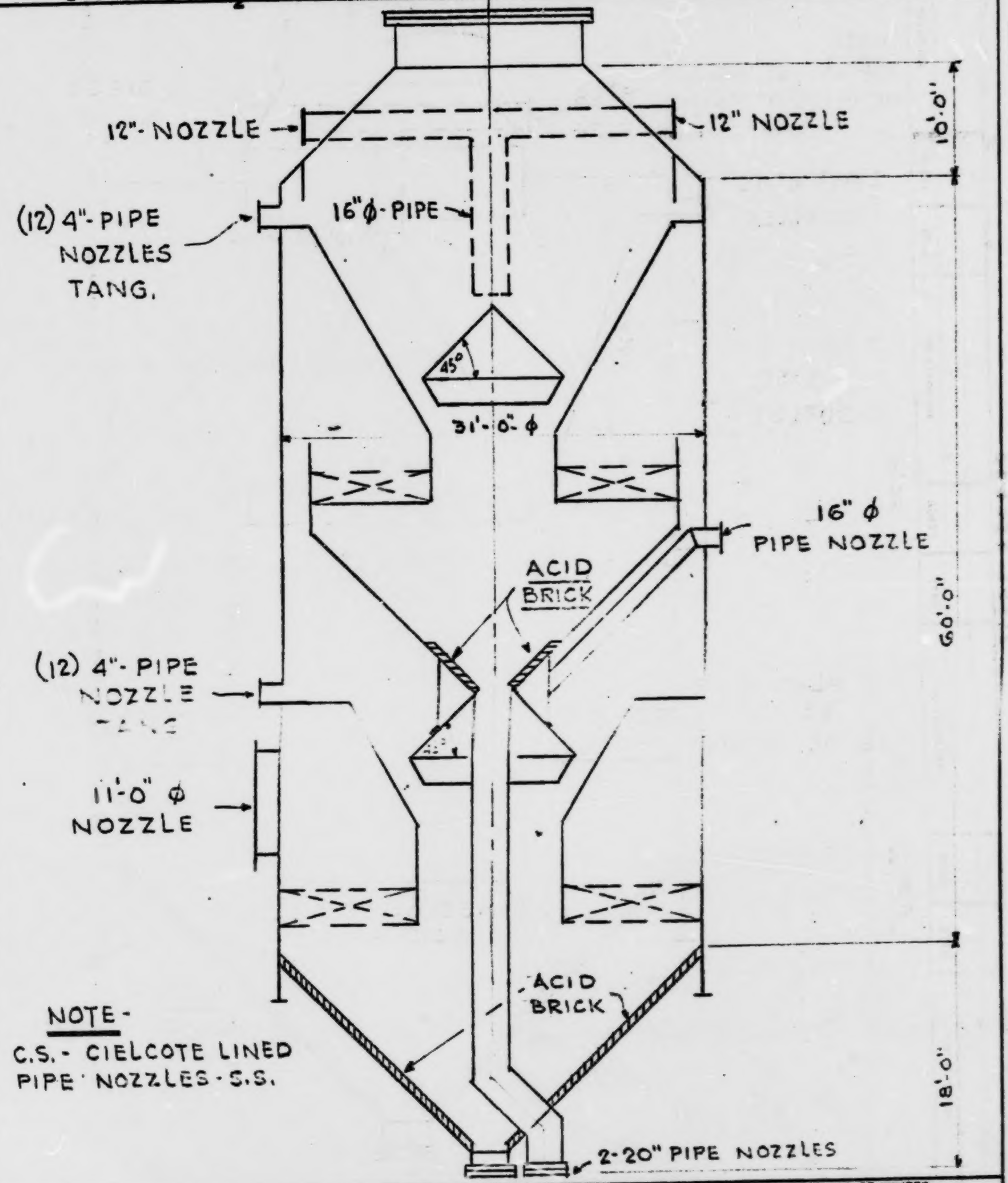
ISSUE RECORD

PREPARED BY:	DATE:	AUTHORIZATION NUMBER	REFERENCE NUMBER R-604
FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION ☐ AND AS NOTED HEREON			SHEET OF

CHEMICAL CONSTRUCTION CORPORATION

CLIENT AND LOCATION
High Sulfur Combustor Study
PLANT SECTION NAME AND SECTION NUMBER
Intermediate Chemical Product -S° 100 T/D

Two-Stage SO_2 Absorber


12"- NOZZLE
12" NOZZLE
10'-0"
(12) 4"- PIPE NOZZLES TANG.
16"ϕ - PIPE
45°
31'-0" ϕ
16" ϕ PIPE NOZZLE
ACID BRICK
60'-0"
(12) 4"- PIPE NOZZLE TANG.
45°
11'-0" ϕ NOZZLE
ACID BRICK
18'-0"
NOTE -
C.S. - CIELCOTE LINED
PIPE NOZZLES - S.S.
2-20" PIPE NOZZLES

ISSUE RECORD

ISSUE	DATE	APPROVED BY

PREPARED BY:
DATE:
FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION AND AS NOTED HEREON
☐
AUTHORIZATION NUMBER
REFERENCE NUMBER
R-201
SHEET OF

04 - 4551 REV. 1

CHEMICAL CONSTRUCTION CORPORATION
VESSEL DATA SHEET "A"

ISSUE RECORD

DATE
APPROVED BY
ISSUE
DATE
APPROVED BY
ISSUE
DATE
APPROVED BY
ISSUE
DATE
APPROVED BY
ISSUE

CLIENT AND LOCATION
High Sulfur Combustor Study

PLANT SECTION NAME AND SECTION NUMBER
Intermediate Chemical Product - S° 100 T/D

Magnesium Oxide Slurry Tank

DESIGN DATA

	CODE
SP. GR. – PRODUCT 1.105	CODE STAMP ☐ YES ☐ NO
WORKING PRESS. PSIG	STRESS RELIEVED
DESIGN PRESS PSIG	RADIOGRAPHED ☐ SPOT ☐ FULLY
WORKING TEMP 155 Max. F	HAMMER TEST
DESIGN TEMP F	WIND PRESSURE
JOINT EFFICIENCY %	**CORROSION ALLOWANCE**
HYDROSTATIC TEST	HEAD
EARTHQUAKE FACTOR	
	SHELL
ERECTION WEIGHT LB	INTERNAL PARTS
OPERATING WEIGHT LB	

WEIGHT OF VESSEL FILLED WITH 370,000 LB
CONSTRUCTION

INSPECTION BY

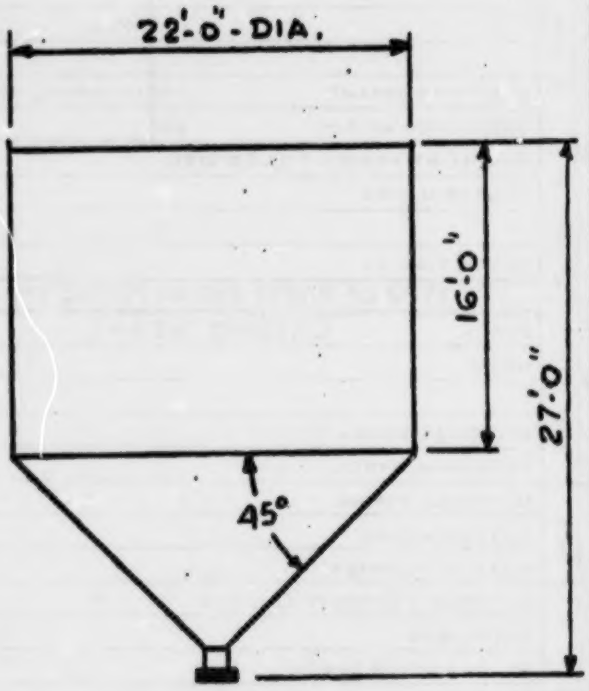
TYPE OF PARTS AND MATERIAL SPECIFICATION

SHELL Carbon Steel
HEAD

INTERNAL STEEL
EXTERNAL STEEL
INTERNAL PIPING
NOZZLE NECKS
NOZZLE FLANGES
MANHOLE – ☐ DAVIT ☐ HINGE
COUPLINGS
STUDS AND/OR BOLTS
NUTS
GASKETS

INSULATION SUPPORTS
INSULATION
PAINT

① MEASURED FROM ℄ OF VESSEL TO FACE OF FLANGE
② VESSEL SUPPORTED ON ☐ STEEL ☐ CONCRETE ☐
③ VESSEL TOLERANCE – SEE STD. EF-1
④



NOZZLE DATA

NOZZLE	SIZE	ASA RATING	NOZZLE SCH	FLANGE TYPE	FLANGE FACE	DIM "A" ①	REMARKS
A 1							
A 2							
A 3							
A 4							
A 5							
A 6							
A 7							
A 8							
A 9							
A 10							
A 11							
A 12							

PREPARED BY: DATE:
FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION AND AS NOTED HEREON
☐

AUTHORIZATION NUMBER

REFERENCE NUMBER
G-201
SHEET OF

CHEMICAL CONSTRUCTION CORPORATION
VESSEL DATA SHEET "A"

ISSUE RECORD

DATE · APPROVED BY · ISSUE · DATE · APPROVED BY · ISSUE · DATE · APPROVED BY · ISSUE · DATE · APPROVED BY · ISSUE

CLIENT AND LOCATION
High Sulfur Combustor Study

PLANT SECTION NAME AND SECTION NUMBER
Intermediate Chemical Product -S^{o} 100 T/D

Recycle Tank

DESIGN DATA

		CODE	
SP. GR. – PRODUCT		CODE STAMP ☐ YES ☐ NO	
WORKING PRESS.	ATM PSIG	STRESS RELIEVED	
DESIGN PRESS	PSIG	RADIOGRAPHED ☐ SPOT ☐ FULLY	
WORKING TEMP	120°F F	HAMMER TEST	
DESIGN TEMP	F	WIND PRESSURE	
JOINT EFFICIENCY	%	**CORROSION ALLOWANCE**	
HYDROSTATIC TEST		HEAD	
EARTHQUAKE FACTOR			
		SHELL	
ERECTION WEIGHT	LB	INTERNAL PARTS	
OPERATING WEIGHT	LB		

WEIGHT OF VESSEL FILLED WITH LB

CONSTRUCTION

INSPECTION BY

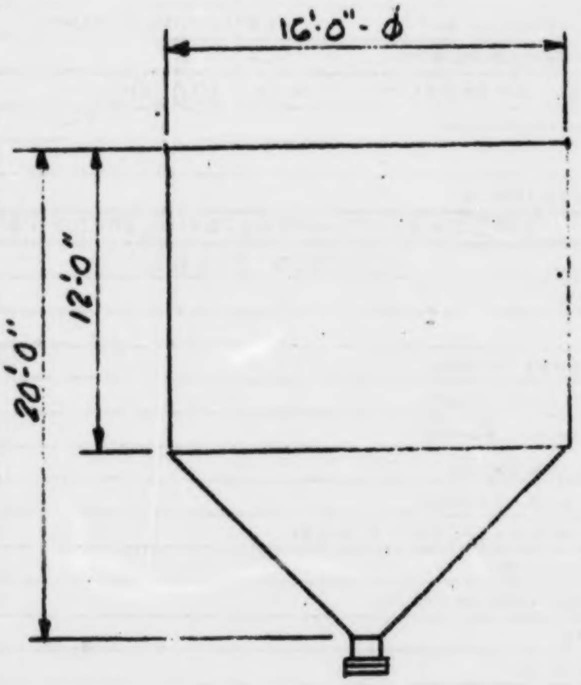
TYPE OF PARTS AND MATERIAL SPECIFICATION

SHELL	Carbon Steel
HEAD	
INTERNAL STEEL	
EXTERNAL STEEL	
INTERNAL PIPING	
NOZZLE NECKS	
NOZZLE FLANGES	
MANHOLE – ☐ DAVIT ☐ HINGE	
COUPLINGS	
STUDS AND/OR BOLTS	
NUTS	
GASKETS	
INSULATION SUPPORTS	
INSULATION	
PAINT	

NOZZLE DATA

NOZZLE	SIZE	ASA	NOZZLE	FLANGE		DIM "A"	REMARKS
		RATING	SCH	TYPE	FACE	①	
A 1							
A 2							
A 3							
A 4							
A 5							
A 6							
A 7							
A 8							
A 9							
A 10							
A 11							
A 12							

① MEASURED FROM ℄ OF VESSEL TO FACE OF FLANGE
② VESSEL SUPPORTED ON ☐ STEEL ☐ CONCRETE ☐
③ VESSEL TOLERANCE – SEE STD. EF-1
④



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FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION AND AS NOTED HEREON ☐

AUTHORIZATION NUMBER

REFERENCE NUMBER
G-601

SHEET OF

CHEMICAL CONSTRUCTION CORPORATION
VESSEL DATA SHEET "A"

CLIENT AND LOCATION
High Sulfur Combustor Study

PLANT SECTION NAME AND SECTION NUMBER
Intermediate Chemical Product $-S^{o}$ 100 T/D

Wet Ash, Iron Oxide Storage Silo

DESIGN DATA

81 lb/cu.ft.	CODE
SP. GR. – PRODUCT	CODE STAMP ☐ YES ☐ NO
WORKING PRESS. PSIG	STRESS RELIEVED
DESIGN PRESS PSIG	RADIOGRAPHED ☐ SPOT ☐ FULLY
WORKING TEMP 200° F	HAMMER TEST
DESIGN TEMP F	WIND PRESSURE
JOINT EFFICIENCY %	**CORROSION ALLOWANCE**
HYDROSTATIC TEST	HEAD
EARTHQUAKE FACTOR	
	SHELL
ERECTION WEIGHT LB	INTERNAL PARTS
OPERATING WEIGHT LB	

WEIGHT OF VESSEL FILLED WITH LB

CONSTRUCTION

INSPECTION BY

TYPE OF PARTS AND MATERIAL SPECIFICATION

SHELL Carbon Steel

HEAD

INTERNAL STEEL

EXTERNAL STEEL

INTERNAL PIPING

NOZZLE NECKS

NOZZLE FLANGES

MANHOLE – ☐ DAVIT ☐ HINGE

COUPLINGS

STUDS AND/OR BOLTS

NUTS

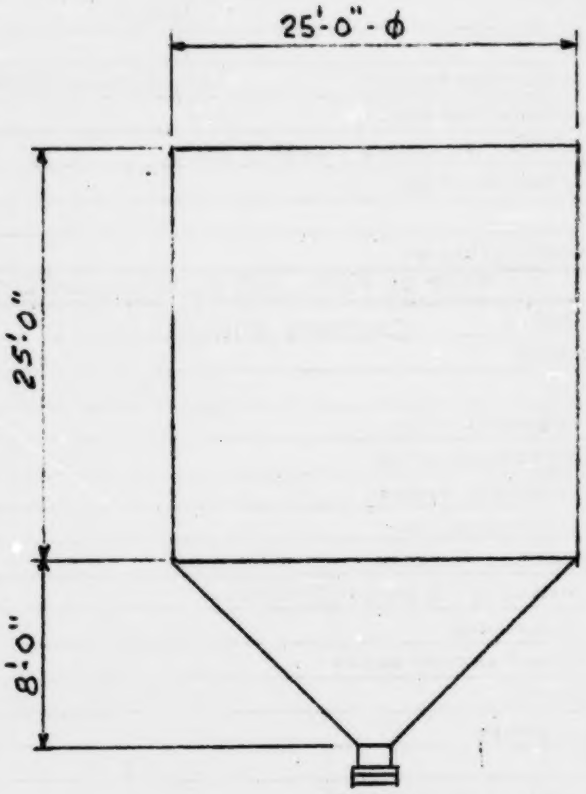
GASKETS

INSULATION SUPPORTS

INSULATION

PAINT

① MEASURED FROM ℄ OF VESSEL TO FACE OF FLANGE
② VESSEL SUPPORTED ON ☐ STEEL ☐ CONCRETE ☐
③ VESSEL TOLERANCE – SEE STD. EF-1
④



NOZZLE DATA

NOZZLE	SIZE	ASA RATING	NOZZLE SCH	FLANGE TYPE	FLANGE FACE	DIM "A" ①	REMARKS
A 1							
A 2							
A 3							
A 4							
A 5							
A 6							
A 7							
A 8							
A 9							
A 10							
A 11							
A 12							

ISSUE RECORD

DATE
APPROVED BY
ISSUE
DATE
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ISSUE
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DATE
APPROVED BY
ISSUE

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AUTHORIZATION NUMBER

REFERENCE NUMBER
I-601A

SHEET OF

94 4549

CHEMICAL CONSTRUCTION CORPORATION
VESSEL DATA SHEET "A"

ISSUE RECORD

DATE	APPROVED BY	ISSUE	DATE

CLIENT AND LOCATION
High Sulfur Combustor Study

PLANT SECTION NAME AND SECTION NUMBER
Intermediate Chemical Product -S^o 100 T/D

Lime Storage Bin

DESIGN DATA

27 lbs/cu.ft.	CODE
SP. GR. – PRODUCT	CODE STAMP ☐ YES ☐ NO
WORKING PRESS. PSIG	STRESS RELIEVED
DESIGN PRESS PSIG	RADIOGRAPHED ☐ SPOT ☐ FULLY
WORKING TEMP Ambient F	HAMMER TEST
DESIGN TEMP F	WIND PRESSURE
JOINT EFFICIENCY %	**CORROSION ALLOWANCE**
HYDROSTATIC TEST	HEAD
EARTHQUAKE FACTOR	
	SHELL
ERECTION WEIGHT LB	INTERNAL PARTS
OPERATING WEIGHT LB	

WEIGHT OF VESSEL FILLED WITH LB

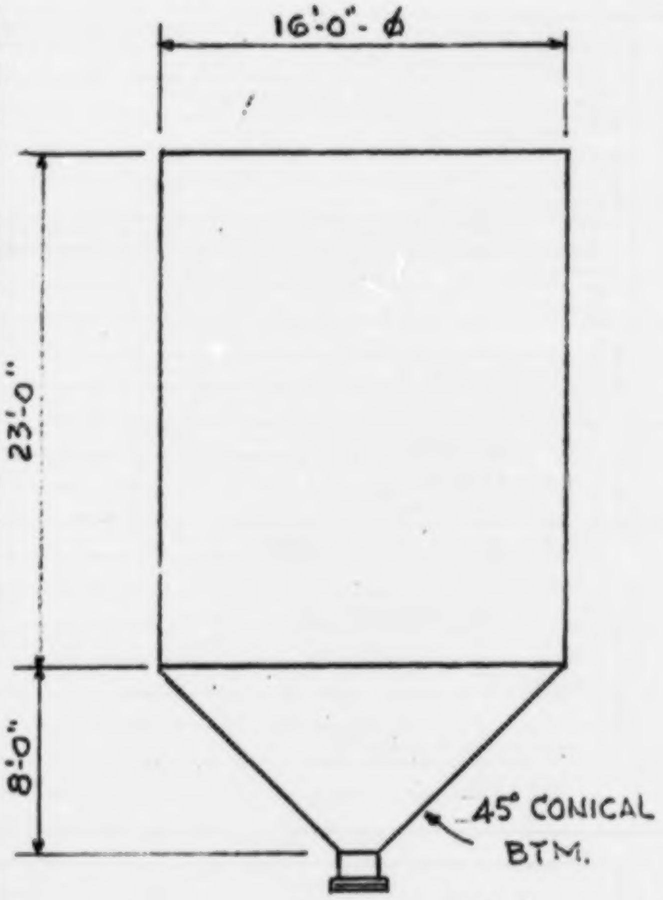
CONSTRUCTION

INSPECTION BY

TYPE OF PARTS AND MATERIAL SPECIFICATION

SHELL Carbon Steel
HEAD
INTERNAL STEEL
EXTERNAL STEEL
INTERNAL PIPING
NOZZLE NECKS
NOZZLE FLANGES
MANHOLE – ☐ DAVIT ☐ HINGE
COUPLINGS
STUDS AND/OR BOLTS
NUTS
GASKETS
INSULATION SUPPORTS
INSULATION
PAINT

① MEASURED FROM ℄ OF VESSEL TO FACE OF FLANGE
② VESSEL SUPPORTED ON ☐ STEEL ☐ CONCRETE ☐
③ VESSEL TOLERANCE – SEE STD. EF-1
④



NOZZLE DATA

NOZZLE	SIZE	ASA RATING	NOZZLE SCH	FLANGE TYPE	FLANGE FACE	DIM "A" ①	REMARKS
A 1							
A 2							
A 3							
A 4							
A 5							
A 6							
A 7							
A 8							
A 9							
A 10							
A 11							
A 12							

PREPARED BY:	DATE:	AUTHORIZATION NUMBER	REFERENCE NUMBER I-602
FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION AND AS NOTED HEREON ☐			SHEET OF

04 45[illegible]

CHEMICAL CONSTRUCTION CORPORATION

CENTRIFUGAL PUMP - PROPOSAL DATA SHEET

SHEET OF

CLIENT AND LOCATION: High Sulfur Combustor Study

PLANT SECTION NAME AND SECTION NUMBER: Intermediate Chemical Product -S^o 100 T/D J-601

LIQUID CHARACTERISTICS

LIQUID PUMPED: Water
SPECIFIC GRAVITY AT FLOW TEMPERATURE: 1.0
FLOW TEMPERATURE: 120 Max. °F
VISCOSITY AT FLOW TEMPERATURE (SECONDS SSU):
VAPOR PRESSURE AT FLOW TEMPERATURE: PSIA
PERCENT SOLIDS: 0.0 SIZE SOLIDS

CAPACITIES AND PRESSURES

GPM (US) AT FLOW TEMPERATURE: NORMAL 162 DESIGN
DISCHARGE PRESSURE: PSIG
SUCTION PRESSURE AT PUMP AT FLOW RATE: PSIG
DIFFERENTIAL PRESSURE: PSI
DIFFERENTIAL HEAD (FEET OF LIQUID PUMPED): 200 FEET
NPSH AVAILABLE (CENTER LINE OF IMPELLER): FEET

DRIVER

INTEGRAL OR COUPLED SHAFT:
TYPE DRIVER: ☒ MOTOR ☐ TURBINE
DRIVER TO BE FURNISHED BY:
DRIVER TO BE MOUNTED BY:

CONSTRUCTION REQUIREMENTS

CASING TYPE: ☐ HORIZONTAL SPLIT ☐ VERTICAL SPLIT ☐ BARREL
CASING SUPPORT: ☐ FOOT ☐ VERTICAL ☐ CENTERLINE ☐ BRACKET
BASE PLATE REQUIRED: ☐ YES ☐ NO
EXTENDED FOR DRIVER: ☐ YES ☐ NO. DRAIN RIM REQUIRED: ☐ YES ☐ NO
COUPLING TYPE REQUIRED: GUARD REQUIRED: ☐ YES ☐ NO
STUFFING BOX PACKING REQUIRED: ☐ YES ☐ NO
STUFFING BOX JACKET REQUIRED: ☐ YES ☐ NO
MECHANICAL SEAL REQUIRED: ☐ YES ☐ NO TYPE:
BEARING COOLING REQUIRED: ☐ YES ☐ NO
BY-PASS COOLING ORIFICE PLATES REQUIRED: ☐ YES ☐ NO

MATERIAL CODE	INTERNAL CLASSIFICATION
I - CAST IRON	1 IRON
B - BRONZE	2 BRONZE
S - STEEL	3 STAINLESS STEEL (TYPE)
D - DUCTILE IRON	4 STEEL
C - CHROME STEEL (11-13% CHROME)	5 DUCTILE IRON
SS- STAINLESS STEEL (TYPE)	6 CHROME STEEL
A - ALLOY	
h - HARDENED f - FACED	

EXTERNAL CASING MATERIAL ☐

INTERNAL CLASSIFICATION ☐

INTERNAL CLASSIFICATION IDENTIFICATION	1	2	3	4	5	6	7
IMPELLER	I	B	SS	S	I	C	
INNER CASE PARTS	I	I & B	SS	S	I	C	
SHAFT SLEEVES (PACKED TYPE)	Ch	Ch	SS	Af	Af	Af	
SHAFT SLEEVES (MECH. SEAL TYPE)	C	C	SS	C	C	C	
WEAR RINGS (IF REQUIRE)	I	B	SS	Ch	Ch	Ch	
SHAFT	S	S	SS	S	S	S	

SHOP TESTS	REQUIRED	WITNESSED
RUNNING PERFORMANCE		
NPSH		

REMARKS: Inst. HP = 20

DATE | APPROVED BY | ISSUE | DATE | APPROVED BY | ISSUE

ISSUE RECORD

AUTHORIZATION NO.

DATE:

PREPARED BY:

FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER SPECIFICATION AND AS NOTED HEREON ☐ STD - SPA - 50 ☐

CHEMICAL CONSTRUCTION CORPORATION
VESSEL DATA SHEET "A"

ISSUE RECORD

DATE
APPROVED BY
ISSUE
DATE
APPROVED BY
ISSUE
DATE
APPROVED BY
ISSUE
DATE
APPROVED BY
ISSUE

CLIENT AND LOCATION: High Sulfur Combustor Study

PLANT SECTION NAME AND SECTION NUMBER: Intermediate Chemical Product - S^o 100 T/D

Fly Ash Iron Oxide Thickeners

DESIGN DATA

	CODE
SP. GR. - PRODUCT 1.08-1.17	CODE STAMP ☐ YES ☐ NO
WORKING PRESS. PSIG	STRESS RELIEVED
DESIGN PRESS PSIG	RADIOGRAPHED ☐ SPOT ☐ FULLY
WORKING TEMP 133 F	HAMMER TEST
DESIGN TEMP F	WIND PRESSURE
JOINT EFFICIENCY %	**CORROSION ALLOWANCE**
HYDROSTATIC TEST	HEAD
EARTHQUAKE FACTOR	
	SHELL
ERECTION WEIGHT LB	INTERNAL PARTS
OPERATING WEIGHT LB	

WEIGHT OF VESSEL FILLED WITH LB

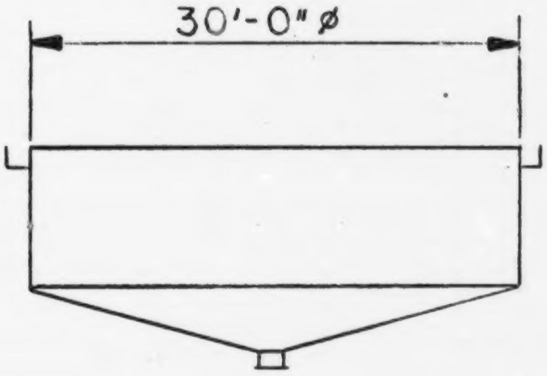
CONSTRUCTION

INSPECTION BY

TYPE OF PARTS AND MATERIAL SPECIFICATION

SHELL Rubber Lined Carbon Steel
HEAD
INTERNAL STEEL
EXTERNAL STEEL
INTERNAL PIPING
NOZZLE NECKS
NOZZLE FLANGES
MANHOLE - ☐ DAVIT ☐ HINGE
COUPLINGS
STUDS AND/OR BOLTS
NUTS
GASKETS
INSULATION SUPPORTS
INSULATION
PAINT

① MEASURED FROM ℄ OF VESSEL TO FACE OF FLANGE
② VESSEL SUPPORTED ON ☐ STEEL ☐ CONCRETE ☐
③ VESSEL TOLERANCE - SEE STD. EF-1
④



NOZZLE DATA

NOZZLE	SIZE	ASA RATING	NOZZLE SCH	FLANGE TYPE	FLANGE FACE	DIM "A" ①	REMARKS
A 1							
A 2							
A 3							
A 4							
A 5							
A 6							
A 7							
A 8							
A 9							
A 10							
A 11							
A 12							

PREPARED BY: DATE:

FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION ☐ AND AS NOTED HEREON

AUTHORIZATION NUMBER

REFERENCE NUMBER R-602 A&B

SHEET OF

04-4549

CHEMICAL CONSTRUCTION CORPORATION

CENTRIFUGAL PUMP - PROPOSAL DATA SHEET

SHEET OF

ISSUE RECORD

DATE

APPROVED BY

ISSUE

DATE

APPROVED BY

ISSUE

AUTHORIZATION NO.

DATE:

PREPARED BY:

FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER SPECIFICATION AND AS NOTED HEREON

☐ STD - SPA - 50 ☐

CLIENT AND LOCATION: High Sulfur Combustor Study

PLANT SECTION NAME AND SECTION NUMBER: Intermediate Chemicl Product -S^o 100 T/D J-602

LIQUID CHARACTERISTICS

LIQUID PUMPED: Slurry Fly Ash and Iron Oxide in Dilute H_2SO_4

SPECIFIC GRAVITY AT FLOW TEMPERATURE: 1.165

FLOW TEMPERATURE: 145 Max. °F

VISCOSITY AT FLOW TEMPERATURE (CENTIPOISE) (SSU):

VAPOR PRESSURE AT FLOW TEMPERATURE: PSIA

PERCENT SOLIDS: 25 SIZE SOLIDS

CAPACITIES AND PRESSURES

GPM (US) AT FLOW TEMPERATURE: NORMAL 27 DESIGN

DISCHARGE PRESSURE: PSIG

SUCTION PRESSURE AT PUMP AT FLOW RATE: PSIG

DIFFERENTIAL PRESSURE: PSI

DIFFERENTIAL HEAD (FEET OF LIQUID PUMPED): 30 FEET

NPSH AVAILABLE (CENTER LINE OF IMPELLER): FEET

DRIVER

INTEGRAL OR COUPLED SHAFT:

TYPE DRIVER: ☒ MOTOR ☐ TURBINE

DRIVER TO BE FURNISHED BY:

DRIVER TO BE MOUNTED BY:

CONSTRUCTION REQUIREMENTS

CASING TYPE: ☐ HORIZONTAL SPLIT ☐ VERTICAL SPLIT ☐ BARREL

CASING SUPPORT: ☐ FOOT ☐ VERTICAL ☐ CENTERLINE ☐ BRACKET

BASE PLATE REQUIRED: ☐ YES ☐ NO

EXTENDED FOR DRIVER: ☐ YES ☐ NO. DRAIN RIM REQUIRED: ☐ YES ☐ NO

COUPLING TYPE REQUIRED: GUARD REQUIRED: ☐ YES ☐ NO

STUFFING BOX PACKING REQUIRED: ☐ YES ☐ NO

STUFFING BOX JACKET REQUIRED: ☐ YES ☐ NO

MECHANICAL SEAL REQUIRED: ☐ YES ☐ NO TYPE:

BEARING COOLING REQUIRED: ☐ YES ☐ NO

BY-PASS COOLING ORIFICE PLATES REQUIRED: ☐ YES ☐ NO

MATERIAL CODE	INTERNAL CLASSIFICATION
I - CAST IRON B - BRONZE S - STEEL D - DUCTILE IRON C - CHROME STEEL (11-13% CHROME) SS- STAINLESS STEEL (TYPE) A - ALLOY h - HARDENED f - FACED	1 IRON 2 BRONZE 3 STAINLESS STEEL (TYPE) 4 STEEL 5 DUCTILE IRON 6 CHROME STEEL

EXTERNAL CASING MATERIAL ☐

INTERNAL CLASSIFICATION ☐

INTERNAL CLASSIFICATION IDENTIFICATION	1	2	3	4	5	6	7
IMPELLER	I	B	SS	S	I	C	
INNER CASE PARTS	I	I & B	SS	S	I	C	
SHAFT SLEEVES (PACKED TYPE)	Ch	Ch	SS	Af	Af	Af	
SHAFT SLFEVES (MECH. SEAL TYPE)	C	C	SS	C	C	C	
WEAR RINGS (IF REQUIRE)	I	B	SS	Ch	Ch	Ch	
SHAFT	S	S	SS	S	S	S	

SHOP TESTS	REQUIRED	WITNESSED
RUNNING PERFORMANCE		
NPSH		

REMARKS: Inst. HP = 2.0

CHEMICAL CONSTRUCTION CORPORATION
VESSEL WITH FLAT BOTTOM AND OPEN HEAD - TYPE 1

ISSUE RECORD

DATE | APPROVED BY | ISSUE | DATE | APPROVED BY | ISSUE | DATE | APPROVED BY | ISSUE | DATE | APPROVED BY | ISSUE

CLIENT AND LOCATION
High Sulfur Combustor Study

PLANT SECTION NAME AND SECTION NUMBER
Intermediate Chemical Product $-S^o$ 100 T/D, Thickener Overflow Tan

DESIGN DATA

CHEMICO SPEC. NO.		CODE	
SP.GR.—PRODUCT		CODE STAMP ☐ YES ☐ NO	
WORKING PRESS.	PSIG	STRESS RELIEVED	
DESIGN PRESS.	PSIG	RADIOGRAPHED	
WORKING TEMP. 135	F	HAMMER TEST	
DESIGN TEMP	F	WIND PRESSURE	
JOINT EFFICIENCY	%	**CORROSION ALLOWANCE**	
HYDROSTATIC TEST		HEAD	
EARTHQUAKE FACTOR			
		SHELL	
ERECTION WEIGHT	LB	INTERNAL PARTS	
OPERATING WEIGHT	LB		

WEIGHT OF VESSEL FILLED WITH LB

CONSTRUCTION

INSPECTION BY

TYPE OF PARTS AND MATERIAL SPECIFICATION

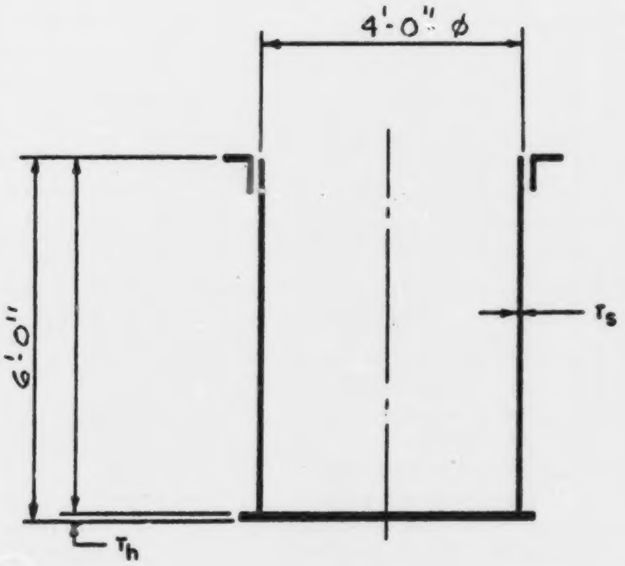
SHELL	Carbon Steel - Rubber Lined
HEAD	
INTERNAL STEEL	
EXTERNAL STEEL	
INTERNAL PIPING	
NOZZLE NECKS	
NOZZLE FLANGES	
MANHOLE — ☐ DAVIT ☐ HINGE	
COUPLINGS	
STUDS AND/OR BOLTS	
NUTS	
GASKETS	
INSULATION SUPPORTS	
INSULATION	
PAINT	

NOZZLE DATA

NOZZLE	SIZE	ASA RATING	NOZZLE SCH	FLANGE TYPE	FLANGE FACE	DIM."A" ①	REMARKS
A 1							
A 2							
A 3							
A 4							
A 5							
A 6							
A 7							
A 8							
A 9							
A 10							
A 11							
A 12							

NOTES

① MEASURED FROM ℄ OF VESSEL TO FACE OF FLANGE
② VESSEL SUPPORTED ON ☐ STEEL; ☐ CONCRETE; ☐
③ VESSEL TOLERANCE — SEE CHEMICO STD. EF - 1



PREPARED BY: DATE:

FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION
☐ STD-SNA-116 ☐ AND AS NOTED HEREON

AUTHORIZATION NO.

REFERENCE NUMBER
G-602

SHEET OF

04 - 455

CHEMICAL CONSTRUCTION CORPORATION

CENTRIFUGAL PUMP - PROPOSAL DATA SHEET

SHEET OF

CLIENT AND LOCATION: High Sulfur Combustor Study

PLANT SECTION NAME AND SECTION NUMBER: Intermediate Chemical Product -S° 100 T/D J-603

ISSUE RECORD

DATE

APPROVED BY

ISSUE

DATE

APPROVED BY

ISSUE

AUTHORIZATION NO.

1 LIQUID CHARACTERISTICS

LIQUID PUMPED: Dilute Sulfuric Acid

SPECIFIC GRAVITY AT FLOW TEMPERATURE: 1.05

FLOW TEMPERATURE: 145°F Max. °F

5 VISCOSITY AT FLOW TEMPERATURE (CENTIPOISE) (SSU):

VAPOR PRESSURE AT FLOW TEMPERATURE: PSIA

PERCENT SOLIDS: < 1% SIZE SOLIDS

CAPACITIES AND PRESSURES

10 GPM (US) AT FLOW TEMPERATURE: NORMAL 133 DESIGN

DISCHARGE PRESSURE: PSIG

SUCTION PRESSURE AT PUMP AT FLOW RATE: PSIG

DIFFERENTIAL PRESSURE: PSI

DIFFERENTIAL HEAD (FEET OF LIQUID PUMPED): 100 FEET

15 NPSH AVAILABLE (CENTER LINE OF IMPELLER): FEET

DRIVER

INTEGRAL OR COUPLED SHAFT:

TYPE DRIVER: ☒ MOTOR ☐ TURBINE

20 DRIVER TO BE FURNISHED BY:

DRIVER TO BE MOUNTED BY:

CONSTRUCTION REQUIREMENTS

CASING TYPE: ☐ HORIZONTAL SPLIT ☐ VERTICAL SPLIT ☐ BARREL

25 CASING SUPPORT: ☐ FOOT ☐ VERTICAL ☐ CENTERLINE ☐ BRACKET

BASE PLATE REQUIRED: ☐ YES ☐ NO

EXTENDED FOR DRIVER: ☐ YES ☐ NO. DRAIN RIM REQUIRED: ☐ YES ☐ NO

COUPLING TYPE REQUIRED: GUARD REQUIRED: ☐ YES ☐ NO

STUFFING BOX PACKING REQUIRED: ☐ YES ☐ NO

30 STUFFING BOX JACKET REQUIRED: ☐ YES ☐ NO

MECHANICAL SEAL REQUIRED: ☐ YES ☐ NO TYPE:

BEARING COOLING REQUIRED: ☐ YES ☐ NO

BY-PASS COOLING ORIFICE PLATES REQUIRED: ☐ YES ☐ NO

35

MATERIAL CODE	INTERNAL CLASSIFICATION
I - CAST IRON	1 IRON
B - BRONZE	2 BRONZE
S - STEEL	3 STAINLESS STEEL (TYPE)
D - DUCTILE IRON	4 STEEL
C - CHROME STEEL (11-13% CHROME)	5 DUCTILE IRON
SS - STAINLESS STEEL (TYPE)	6 CHROME STEEL
A - ALLOY	
h - HARDENED f - FACED	

EXTERNAL CASING MATERIAL ☐

INTERNAL CLASSIFICATION ☐

INTERNAL CLASSIFICATION IDENTIFICATION	1	2	3	4	5	6	7
IMPELLER	I	B	SS	S	I	C	
INNER CASE PARTS	I	I & B	SS	S	I	C	
SHAFT SLEEVES (PACKED TYPE)	Ch	Ch	SS	Af	Af	Af	
SHAFT SLEEVES (MECH. SEAL TYPE)	C	C	SS	C	C	C	
WEAR RINGS (IF REQUIRE)	I	B	SS	Ch	Ch	Ch	
SHAFT	S	S	SS	S	S	S	

40

45

50

SHOP TESTS	REQUIRED	WITNESSED
RUNNING PERFORMANCE		
NPSH		

55 REMARKS: Inst. HP = 7.0

DATE:

PREPARED BY:

FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER SPECIFICATION AND AS NOTED HEREON ☐

STD - SPA - 50 ☐

09 - 4926

CHEMICAL CONSTRUCTION CORPORATION

CENTRIFUGAL PUMP - PROPOSAL DATA SHEET

SHEET OF

CLIENT AND LOCATION: High Sulfur Combustor Study

PLANT SECTION NAME AND SECTION NUMBER: Intermediate Chemical Product -S^o 100 T/D J-604

LIQUID CHARACTERISTICS

LIQUID PUMPED: Ash-Iron Oxide Solids in Dilute Sulfuric Acid

SPECIFIC GRAVITY AT FLOW TEMPERATURE: 1.083

FLOW TEMPERATURE: 145 Max. °F

VISCOSITY AT FLOW TEMPERATURE (CENTIPOISE) (SSU):

VAPOR PRESSURE AT FLOW TEMPERATURE: PSIA

PERCENT SOLIDS: 5.0 SIZE SOLIDS

CAPACITIES AND PRESSURES

GPM (US) AT FLOW TEMPERATURE: NORMAL DESIGN

DISCHARGE PRESSURE: PSIG

SUCTION PRESSURE AT PUMP AT FLOW RATE: PSIG

DIFFERENTIAL PRESSURE: PSI

DIFFERENTIAL HEAD (FEET OF LIQUID PUMPED): 90 FEET

NPSH AVAILABLE (CENTER LINE OF IMPELLER): FEET

DRIVER

INTEGRAL OR COUPLED SHAFT:

TYPE DRIVER: ☒ MOTOR ☐ TURBINE

DRIVER TO BE FURNISHED BY:

DRIVER TO BE MOUNTED BY:

CONSTRUCTION REQUIREMENTS

CASING TYPE: ☐ HORIZONTAL SPLIT ☐ VERTICAL SPLIT ☐ BARREL

CASING SUPPORT: ☐ FOOT ☐ VERTICAL ☐ CENTERLINE ☐ BRACKET

BASE PLATE REQUIRED: ☐ YES ☐ NO

EXTENDED FOR DRIVER: ☐ YES ☐ NO. DRAIN RIM REQUIRED: ☐ YES ☐ NO

COUPLING TYPE REQUIRED: GUARD REQUIRED: ☐ YES ☐ NO

STUFFING BOX PACKING REQUIRED: ☐ YES ☐ NO

STUFFING BOX JACKET REQUIRED: ☐ YES ☐ NO

MECHANICAL SEAL REQUIRED: ☐ YES ☐ NO TYPE:

BEARING COOLING REQUIRED: ☐ YES ☐ NO

BY-PASS COOLING ORIFICE PLATES REQUIRED: ☐ YES ☐ NO

MATERIAL CODE

- I - CAST IRON
- B - BRONZE
- S - STEEL
- D - DUCTILE IRON
- C - CHROME STEEL (11-13% CHROME)
- SS- STAINLESS STEEL (TYPE)
- A - ALLOY
- h - HARDENED
- f - FACED

INTERNAL CLASSIFICATION

1. IRON
2. BRONZE
3. STAINLESS STEEL (TYPE)
4. STEEL
5. DUCTILE IRON
6. CHROME STEEL

EXTERNAL CASING MATERIAL ☐

INTERNAL CLASSIFICATION ☐

INTERNAL CLASSIFICATION IDENTIFICATION	1	2	3	4	5	6	7
IMPELLER	I	B	SS	S	I	C	
INNER CASE PARTS	I	I & B	SS	S	I	C	
SHAFT SLEEVES (PACKED TYPE)	Ch	Ch	SS	Af	Af	Af	
SHAFT SLEEVES (MECH. SEAL TYPE)	C	C	SS	C	C	C	
WEAR RINGS (IF REQUIRE)	I	B	SS	Ch	Ch	Ch	
SHAFT	S	S	SS	S	S	S	

SHOP TESTS	REQUIRED	WITNESSED
RUNNING PERFORMANCE		
NPSH		

REMARKS: Inst. HP = 200

ISSUE RECORD

DATE	APPROVED BY	ISSUE	DATE	APPROVED BY	ISSUE

AUTHORIZATION NO.

DATE:

PREPARED BY:

FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER SPECIFICATION AND AS NOTED HEREON

☐ STD - SPA - 50

09 - 4926

CHEMICAL CONSTRUCTION CORPORATION

VESSEL DATA SHEET "A"

CLIENT AND LOCATION
HIGH SULFUR COMBUSTOR STUDY

PLANT SECTION NAME AND SECTION NUMBER
INTERMEDIATE CHEMICAL PRODUCT – S^{o}100 T/D

LIME SLURRY TANK

DESIGN DATA

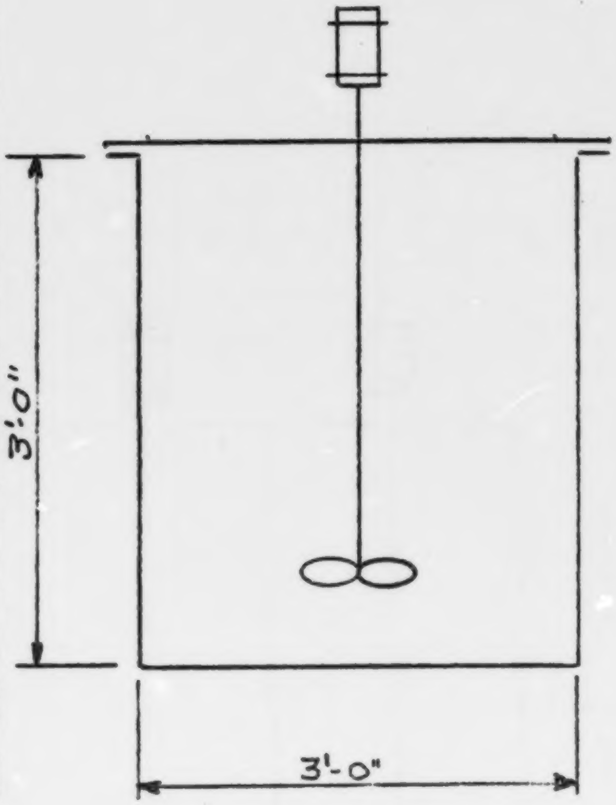
	CODE
SP. GR. – PRODUCT 1.25	CODE STAMP ☐ YES ☐ NO
WORKING PRESS. PSIG	STRESS RELIEVED
DESIGN PRESS PSIG	RADIOGRAPHED ☐ SPOT ☐ FULLY
WORKING TEMP 170–220 F	HAMMER TEST
DESIGN TEMP 250 F	WIND PRESSURE
JOINT EFFICIENCY %	**CORROSION ALLOWANCE**
HYDROSTATIC TEST	HEAD
EARTHQUAKE FACTOR	
	SHELL
ERECTION WEIGHT LB	INTERNAL PARTS
OPERATING WEIGHT LB	

WEIGHT OF VESSEL FILLED WITH LB
CONSTRUCTION
INSPECTION BY

TYPE OF PARTS AND MATERIAL SPECIFICATION

SHELL Carbon Steel
HEAD
INTERNAL STEEL
EXTERNAL STEEL
INTERNAL PIPING
NOZZLE NECKS
NOZZLE FLANGES
MANHOLE – ☐ DAVIT ☐ HINGE
COUPLINGS
STUDS AND/OR BOLTS
NUTS
GASKETS
INSULATION SUPPORTS
INSULATION
PAINT

① MEASURED FROM ℄ OF VESSEL TO FACE OF FLANGE
② VESSEL SUPPORTED ON ☐ STEEL ☐ CONCRETE ☐
③ VESSEL TOLERANCE – SEE STD. EF-1
④



NOZZLE DATA

NOZZLE	SIZE	ASA RATING	NOZZLE SCH	FLANGE TYPE	FLANGE FACE	DIM "A" ①	REMARKS
A 1							
A 2							
A 3							
A 4							
A 5							
A 6							
A 7							
A 8							
A 9							
A 10							
A 11							
A 12							

PREPARED BY: DATE:	AUTHORIZATION NUMBER	REFERENCE NUMBER G-603
FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION AND AS NOTED HEREON ☐		SHEET OF

ISSUE RECORD
DATE
APPROVED BY
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ISSUE

CHEMICAL CONSTRUCTION CORPORATION

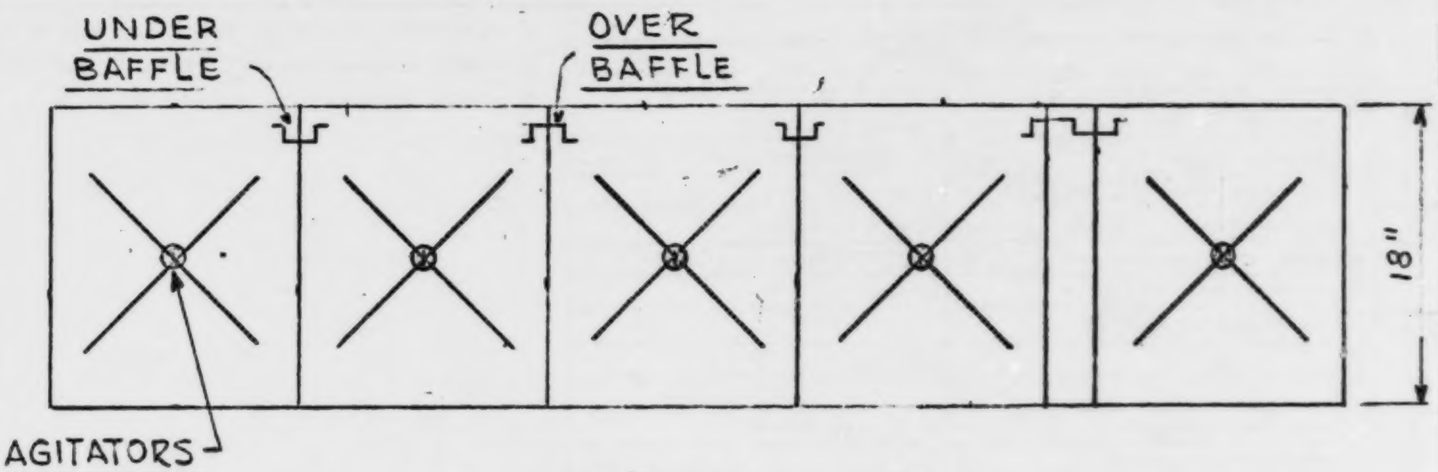
ISSUE RECORD

DATE	APPROVED BY	ISSUE	DATE	APPROVED BY	ISSUE	DATE	APPROVED BY	ISSUE	DATE	APPROVED BY	ISSUE

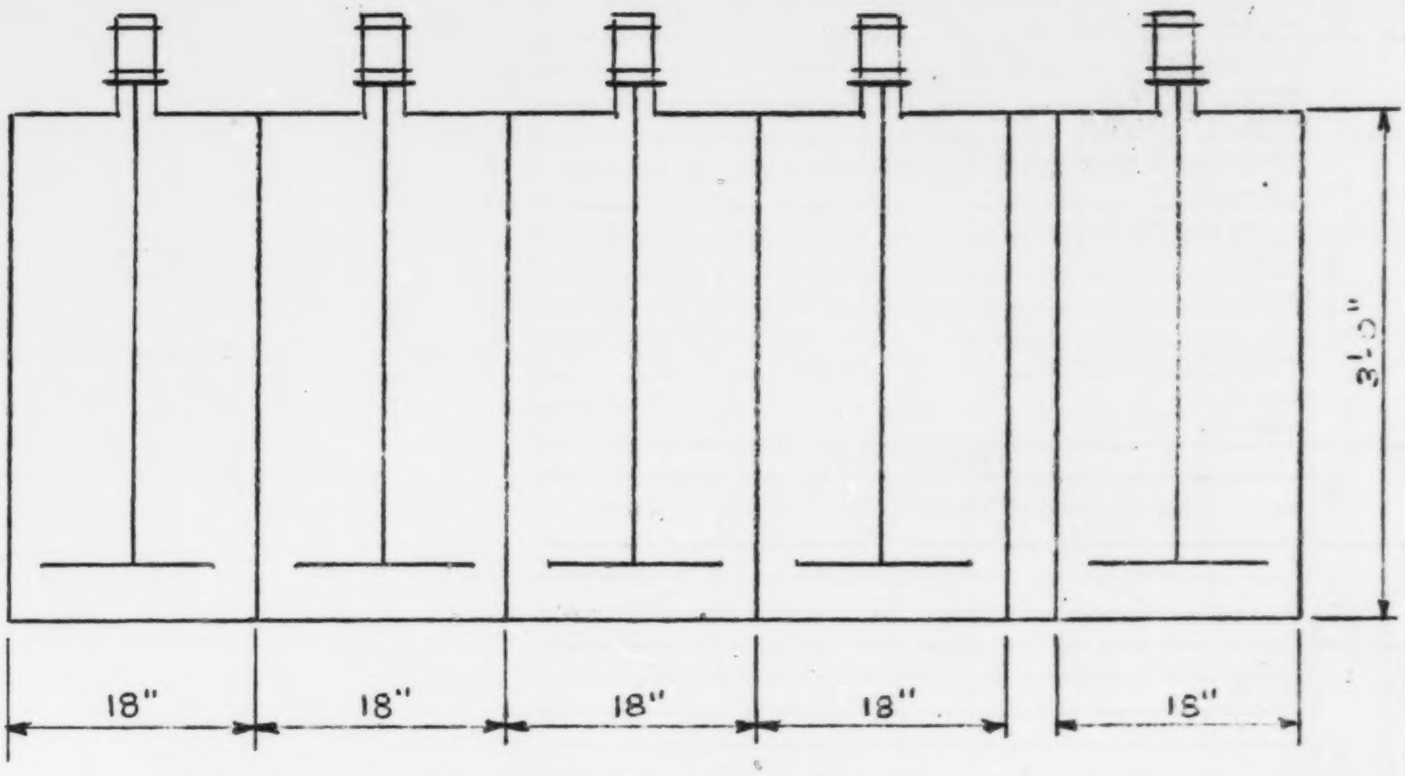
CLIENT AND LOCATION
High Sulfur Combustor Study

PLANT SECTION NAME AND SECTION NUMBER
Intermediate Chemical Product $-S^{o}$ 100 T/D

Neutralization Tanks



PLAN



ELEVATION

PREPARED BY:
DATE:
FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION AND AS NOTED HEREON ☐
AUTHORIZATION NUMBER
REFERENCE NUMBER G-604
SHEET OF

CHEMICAL CONSTRUCTION CORPORATION

CENTRIFUGAL PUMP - PROPOSAL DATA SHEET

SHEET OF

CLIENT AND LOCATION
High Sulfur Combustor Study

PLANT SECTION NAME AND SECTION NUMBER
Intermediate Chemical Product $-S^o$ 100 T/D J-605

ISSUE RECORD

DATE

APPROVED BY

ISSUE

DATE

APPROVED BY

ISSUE

AUTHORIZATION NO.

LIQUID CHARACTERISTICS

LIQUID PUMPED: Hydrated Lime

SPECIFIC GRAVITY AT FLOW TEMPERATURE: 1.2

FLOW TEMPERATURE: 200 Max. °F

VISCOSITY AT FLOW TEMPERATURE (CENTIPOISE) (SSU):

VAPOR PRESSURE AT FLOW TEMPERATURE: PSIA

PERCENT SOLIDS: 35 SIZE SOLIDS

CAPACITIES AND PRESSURES

GPM (US) AT FLOW TEMPERATURE: NORMAL 3.8 DESIGN

DISCHARGE PRESSURE: PSIG

SUCTION PRESSURE AT PUMP AT FLOW RATE: PSIG

DIFFERENTIAL PRESSURE: PSI

DIFFERENTIAL HEAD (FEET OF LIQUID PUMPED): 175 FEET

NPSH AVAILABLE (CENTER LINE OF IMPELLER): FEET

DRIVER

INTEGRAL OR COUPLED SHAFT:

TYPE DRIVER: ☒ MOTOR ☐ TURBINE

DRIVER TO BE FURNISHED BY:

DRIVER TO BE MOUNTED BY:

CONSTRUCTION REQUIREMENTS

CASING TYPE: ☐ HORIZONTAL SPLIT ☐ VERTICAL SPLIT ☐ BARREL

CASING SUPPORT: ☐ FOOT ☐ VERTICAL ☐ CENTERLINE ☐ BRACKET

BASE PLATE REQUIRED: ☐ YES ☐ NO

EXTENDED FOR DRIVER: ☐ YES ☐ NO. DRAIN RIM REQUIRED: ☐ YES ☐ NO

COUPLING TYPE REQUIRED: GUARD REQUIRED: ☐ YES ☐ NO

STUFFING BOX PACKING REQUIRED: ☐ YES ☐ NO

STUFFING BOX JACKET REQUIRED: ☐ YES ☐ NO

MECHANICAL SEAL REQUIRED: ☐ YES ☐ NO TYPE:

BEARING COOLING REQUIRED: ☐ YES ☐ NO

BY-PASS COOLING ORIFICE PLATES REQUIRED: ☐ YES ☐ NO

MATERIAL CODE	INTERNAL CLASSIFICATION
I - CAST IRON B - BRONZE S - STEEL D - DUCTILE IRON C - CHROME STEEL (11-13% CHROME) SS- STAINLESS STEEL (TYPE) A - ALLOY h - HARDENED f - FACED	1 IRON 2 BRONZE 3 STAINLESS STEEL (TYPE) 4 STEEL 5 DUCTILE IRON 6 CHROME STEEL

EXTERNAL CASING MATERIAL ☐

INTERNAL CLASSIFICATION ☐

INTERNAL CLASSIFICATION IDENTIFICATION	1	2	3	4	5	6	7
IMPELLER	I	B	SS	S	I	C	
INNER CASE PARTS	I	I & B	SS	S	I	C	
SHAFT SLEEVES (PACKED TYPE)	Ch	Ch	SS	Af	Af	Af	
SHAFT SLEEVES (MECH. SEAL TYPE)	C	C	SS	C	C	C	
WEAR RINGS (IF REQUIRE)	I	B	SS	Ch	Ch	Ch	
SHAFT	S	S	SS	S	S	S	

SHOP TESTS	REQUIRED	WITNESSED
RUNNING PERFORMANCE		
NPSH		

REMARKS: Inst. HP = 0.5

DATE:

PREPARED BY:

FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER SPECIFICATION AND AS NOTED HEREON

☐ STD - SPA - 50

CHEMICAL CONSTRUCTION CORPORATION

CENTRIFUGAL PUMP - PROPOSAL DATA SHEET

SHEET OF

CLIENT AND LOCATION: High Sulfur Combustor Study

PLANT SECTION NAME AND SECTION NUMBER: Intermediate Chemical Product -S^o 100 T/D J-606

ISSUE RECORD

DATE
APPROVED BY
ISSUE
DATE
APPROVED BY
ISSUE
AUTHORIZATION NO.
DATE:
PREPARED BY:
FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER SPECIFICATION AND AS NOTED HEREON
STD - SPA - 50

LIQUID CHARACTERISTICS

LIQUID PUMPED: Ash-Iron Oxide-Calcium Sulfur Salt Slurry
SPECIFIC GRAVITY AT FLOW TEMPERATURE: 1.28
FLOW TEMPERATURE: 200 °F
VISCOSITY AT FLOW TEMPERATURE (CENTIPOISE) (SSU):
VAPOR PRESSURE AT FLOW TEMPERATURE: PSIA
PERCENT SOLIDS: 33 SIZE SOLIDS

CAPACITIES AND PRESSURES

GPM (US) AT FLOW TEMPERATURE: NORMAL 28.7 DESIGN
DISCHARGE PRESSURE: PSIG
SUCTION PRESSURE AT PUMP AT FLOW RATE: PSIG
DIFFERENTIAL PRESSURE: PSI
DIFFERENTIAL HEAD (FEET OF LIQUID PUMPED): FEET
NPSH AVAILABLE (CENTER LINE OF IMPELLER): FEET

DRIVER

INTEGRAL OR COUPLED SHAFT:
TYPE DRIVER: ☒ MOTOR ☐ TURBINE
DRIVER TO BE FURNISHED BY:
DRIVER TO BE MOUNTED BY:

CONSTRUCTION REQUIREMENTS

CASING TYPE: ☐ HORIZONTAL SPLIT ☐ VERTICAL SPLIT ☐ BARREL
CASING SUPPORT: ☐ FOOT ☐ VERTICAL ☐ CENTERLINE ☐ BRACKET
BASE PLATE REQUIRED: ☐ YES ☐ NO
EXTENDED FOR DRIVER: ☐ YES ☐ NO. DRAIN RIM REQUIRED: ☐ YES ☐ NO
COUPLING TYPE REQUIRED: GUARD REQUIRED: ☐ YES ☐ NO
STUFFING BOX PACKING REQUIRED: ☐ YES ☐ NO
STUFFING BOX JACKET REQUIRED: ☐ YES ☐ NO
MECHANICAL SEAL REQUIRED: ☐ YES ☐ NO TYPE:
BEARING COOLING REQUIRED: ☐ YES ☐ NO
BY-PASS COOLING ORIFICE PLATES REQUIRED: ☐ YES ☐ NO

MATERIAL CODE	INTERNAL CLASSIFICATION
I - CAST IRON	1 IRON
B - BRONZE	2 BRONZE
S - STEEL	3 STAINLESS STEEL (TYPE)
D - DUCTILE IRON	4 STEEL
C - CHROME STEEL (11-13% CHROME)	5 DUCTILE IRON
SS- STAINLESS STEEL (TYPE)	6 CHROME STEEL
A - ALLOY	
h - HARDENED	
f - FACED	

EXTERNAL CASING MATERIAL ☐

INTERNAL CLASSIFICATION ☐

INTERNAL CLASSIFICATION IDENTIFICATION	1	2	3	4	5	6	7
IMPELLER	I	B	SS	S	I	C	
INNER CASE PARTS	I	I & B	SS	S	I	C	
SHAFT SLEEVES (PACKED TYPE)	Ch	Ch	SS	Af	Af	Af	
SHAFT SLEEVES (MECH. SEAL TYPE)	C	C	SS	C	C	C	
WEAR RINGS (IF REQUIRE)	I	B	SS	Ch	Ch	Ch	
SHAFT	S	S	SS	S	S	S	

SHOP TESTS	REQUIRED	WITNESSED
RUNNING PERFORMANCE		
NPSH		

REMARKS: Inst. HP = 2

CHEMICAL CONSTRUCTION CORPORATION
VESSEL DATA SHEET "A"

CLIENT AND LOCATION
High Sulfur Combustor Study

PLANT SECTION NAME AND SECTION NUMBER
Intermediate Chemical Product $-S^{o}$ 100 T/D

Coke Storage Bin

DESIGN DATA

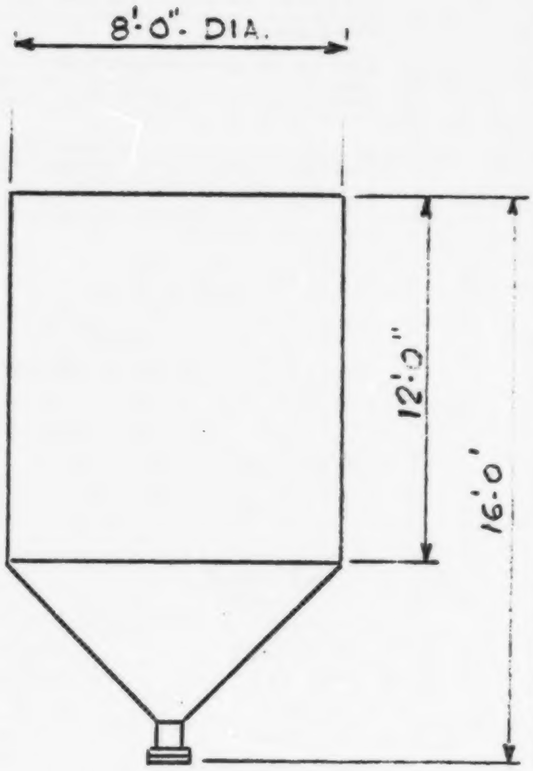
25 lb/cu.ft.	CODE
SP. GR. – PRODUCT	CODE STAMP ☐ YES ☐ NO
WORKING PRESS. PSIG	STRESS RELIEVED
DESIGN PRESS PSIG	RADIOGRAPHED ☐ SPOT ☐ FULLY
WORKING TEMP AMB. F	HAMMER TEST
DESIGN TEMP F	WIND PRESSURE
JOINT EFFICIENCY %	**CORROSION ALLOWANCE**
HYDROSTATIC TEST	HEAD
EARTHQUAKE FACTOR	
	SHELL
ERECTION WEIGHT LB	INTERNAL PARTS
OPERATING WEIGHT LB	

WEIGHT OF VESSEL FILLED WITH 15,000 LB
CONSTRUCTION
INSPECTION BY

① MEASURED FROM ℄ OF VESSEL TO FACE OF FLANGE
② VESSEL SUPPORTED ON ☐ STEEL ☐ CONCRETE ☐
③ VESSEL TOLERANCE – SEE STD. EF-1
④

TYPE OF PARTS AND MATERIAL SPECIFICATION

SHELL Carbon Steel
HEAD
INTERNAL STEEL
EXTERNAL STEEL
INTERNAL PIPING
NOZZLE NECKS
NOZZLE FLANGES
MANHOLE – ☐ DAVIT ☐ HINGE
COUPLINGS
STUDS AND/OR BOLTS
NUTS
GASKETS
INSULATION SUPPORTS
INSULATION
PAINT



NOZZLE DATA

NOZZLE	SIZE	ASA RATING	NOZZLE SCH	FLANGE TYPE	FLANGE FACE	DIM "A" ①	REMARKS
A 1							
A 2							
A 3							
A 4							
A 5							
A 6							
A 7							
A 8							
A 9							
A 10							
A 11							
A 12							

ISSUE RECORD
DATE
APPROVED BY
ISSUE

PREPARED BY: DATE:
AUTHORIZATION NUMBER
REFERENCE NUMBER I-201
FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION AND AS NOTED HEREON ☐
SHEET OF

04-4549

CHEMICAL CONSTRUCTION CORPORATION

CENTRIFUGAL PUMP - PROPOSAL DATA SHEET

SHEET OF

ISSUE RECORD

DATE

APPROVED BY

ISSUE

DATE

APPROVED BY

ISSUE

AUTHORIZATION NO.

DATE:

PREPARED BY:

FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER SPECIFICATION AND AS NOTED HEREON

☐ STD - SPA - 50

CLIENT AND LOCATION: High Sulfur Combustor Study

PLANT SECTION NAME AND SECTION NUMBER: Intermediate Chemical Product -S^o 100 T/D J-205

LIQUID CHARACTERISTICS

LIQUID PUMPED: Magnesium Oxide Slurry

SPECIFIC GRAVITY AT FLOW TEMPERATURE: 1.1

FLOW TEMPERATURE: 135 °F

VISCOSITY AT FLOW TEMPERATURE (CENTIPOISE) (SSU):

VAPOR PRESSURE AT FLOW TEMPERATURE: PSIA

PERCENT SOLIDS: 4% SIZE SOLIDS

CAPACITIES AND PRESSURES

GPM (US) AT FLOW TEMPERATURE: NORMAL 951 DESIGN

DISCHARGE PRESSURE: PSIG

SUCTION PRESSURE AT PUMP AT FLOW RATE: PSIG

DIFFERENTIAL PRESSURE: PSI

DIFFERENTIAL HEAD (FEET OF LIQUID PUMPED): 225 FEET

NPSH AVAILABLE (CENTER LINE OF IMPELLER): FEET

DRIVER

INTEGRAL OR COUPLED SHAFT:

TYPE DRIVER: ☒ MOTOR ☐ TURBINE

DRIVER TO BE FURNISHED BY:

DRIVER TO BE MOUNTED BY:

CONSTRUCTION REQUIREMENTS

CASING TYPE: ☐ HORIZONTAL SPLIT ☐ VERTICAL SPLIT ☐ BARREL

CASING SUPPORT: ☐ FOOT ☐ VERTICAL ☐ CENTERLINE ☐ BRACKET

BASE PLATE REQUIRED: ☐ YES ☐ NO

EXTENDED FOR DRIVER: ☐ YES ☐ NO. DRAIN RIM REQUIRED: ☐ YES ☐ NO

COUPLING TYPE REQUIRED: GUARD REQUIRED: ☐ YES ☐ NO

STUFFING BOX PACKING REQUIRED: ☐ YES ☐ NO

STUFFING BOX JACKET REQUIRED: ☐ YES ☐ NO

MECHANICAL SEAL REQUIRED: ☐ YES ☐ NO TYPE:

BEARING COOLING REQUIRED: ☐ YES ☐ NO

BY-PASS COOLING ORIFICE PLATES REQUIRED: ☐ YES ☐ NO

MATERIAL CODE	INTERNAL CLASSIFICATION
I - CAST IRON B - BRONZE S - STEEL D - DUCTILE IRON C - CHROME STEEL (11-13% CHROME) SS- STAINLESS STEEL (TYPE) A - ALLOY h - HARDENED f - FACED	1 IRON 2 BRONZE 3 STAINLESS STEEL (TYPE) 4 STEEL 5 DUCTILE IRON 6 CHROME STEEL

EXTERNAL CASING MATERIAL ☐

INTERNAL CLASSIFICATION ☐

INTERNAL CLASSIFICATION IDENTIFICATION	1	2	3	4	5	6	7
IMPELLER	I	B	SS	S	I	C	
INNER CASE PARTS	I	I & B	SS	S	I	C	
SHAFT SLEEVES (PACKED TYPE)	Ch	Ch	SS	Af	Af	Af	
SHAFT SLEEVES MECH. SEAL TYPE	C	C	SS	C	C	C	
WEAR RINGS (IF REQUIRE)	I	B	SS	Ch	Ch	Ch	
SHAFT	S	S	SS	S	S	S	

SHOP TESTS	REQUIRED	WITNESSED
RUNNING PERFORMANCE		
NPSH		

REMARKS: Inst. HP = 125

CHEMICAL CONSTRUCTION CORPORATION
VESSEL DATA SHEET "A"

CLIENT AND LOCATION
High Sulfur Combustor Study

PLANT SECTION NAME AND SECTION NUMBER
Intermediate Chemical Product - S^{o} 100 T/D

Storage Bin, MgO Make-Up

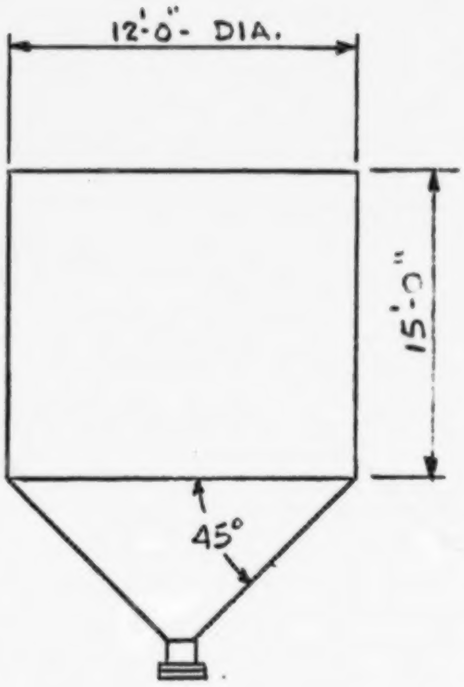
DESIGN DATA

		CODE	
SP. GR. - PRODUCT	25 lbs/cu-ft.	CODE STAMP ☐ YES ☐ NO	
WORKING PRESS.	PSIG	STRESS RELIEVED	
DESIGN PRESS	PSIG	RADIOGRAPHED ☐ SPOT ☐ FULLY	
WORKING TEMP	AMB. F	HAMMER TEST	
DESIGN TEMP	F	WIND PRESSURE	
JOINT EFFICIENCY	%	**CORROSION ALLOWANCE**	
HYDROSTATIC TEST		HEAD	
EARTHQUAKE FACTOR			
		SHELL	
ERECTION WEIGHT	LB	INTERNAL PARTS	
OPERATING WEIGHT	LB		
WEIGHT OF VESSEL FILLED WITH	26,000 LB		
CONSTRUCTION			
INSPECTION BY			

TYPE OF PARTS AND MATERIAL SPECIFICATION

SHELL	Carbon Steel
HEAD	
INTERNAL STEEL	
EXTERNAL STEEL	
INTERNAL PIPING	
NOZZLE NECKS	
NOZZLE FLANGES	
MANHOLE - ☐ DAVIT ☐ HINGE	
COUPLINGS	
STUDS AND/OR BOLTS	
NUTS	
GASKETS	
INSULATION SUPPORTS	
INSULATION	
PAINT	

① MEASURED FROM ℄ OF VESSEL TO FACE OF FLANGE
② VESSEL SUPPORTED ON ☐ STEEL ☐ CONCRETE ☐
③ VESSEL TOLERANCE - SEE STD. EF-1
④



NOZZLE DATA

NOZZLE	SIZE	ASA RATING	NOZZLE SCH	FLANGE TYPE	FLANGE FACE	DIM "A" ①	REMARKS
A 1							
A 2							
A 3							
A 4							
A 5							
A 6							
A 7							
A 8							
A 9							
A 10							
A 11							
A 12							

ISSUE RECORD

PREPARED BY: DATE:	AUTHORIZATION NUMBER	REFERENCE NUMBER I-202
FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION AND AS NOTED HEREON		SHEET OF

CHEMICAL CONSTRUCTION CORPORATION

CENTRIFUGAL PUMP - PROPOSAL DATA SHEET

SHEET OF

ISSUE RECORD: DATE / APPROVED BY / ISSUE / DATE / APPROVED BY / ISSUE

AUTHORIZATION NO.

DATE:

PREPARED BY:

☐ FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER SPECIFICATION AND AS NOTED HEREON

☐ STD - SPA - 50

CLIENT AND LOCATION: High Sulfur Combustor Study

PLANT SECTION NAME AND SECTION NUMBER: Intermediate Chemical Product -S° 100 T/D.J-201

LIQUID CHARACTERISTICS

LIQUID PUMPED: Magnesium Sulfite Slurry

SPECIFIC GRAVITY AT FLOW TEMPERATURE: 1.17

FLOW TEMPERATURE: 133 °F

VISCOSITY AT FLOW TEMPERATURE (CENTIPOISE) (SSU):

VAPOR PRESSURE AT FLOW TEMPERATURE: PSIA

PERCENT SOLIDS: 13 SIZE SOLIDS

CAPACITIES AND PRESSURES

GPM (US) AT FLOW TEMPERATURE: NORMAL DESIGN

DISCHARGE PRESSURE: PSIG

SUCTION PRESSURE AT PUMP AT FLOW RATE: PSIG

DIFFERENTIAL PRESSURE: PSI

DIFFERENTIAL HEAD (FEET OF LIQUID PUMPED): 175 FEET

NPSH AVAILABLE (CENTER LINE OF IMPELLER): FEET

DRIVER

INTEGRAL OR COUPLED SHAFT:

TYPE DRIVER: ☒ MOTOR ☐ TURBINE

DRIVER TO BE FURNISHED BY:

DRIVER TO BE MOUNTED BY:

CONSTRUCTION REQUIREMENTS

CASING TYPE: ☐ HORIZONTAL SPLIT ☐ VERTICAL SPLIT ☐ BARREL

CASING SUPPORT: ☐ FOOT ☐ VERTICAL ☐ CENTERLINE ☐ BRACKET

BASE PLATE REQUIRED: ☐ YES ☐ NO

EXTENDED FOR DRIVER: ☐ YES ☐ NO. DRAIN RIM REQUIRED: ☐ YES ☐ NO

COUPLING TYPE REQUIRED: GUARD REQUIRED: ☐ YES ☐ NO

STUFFING BOX PACKING REQUIRED: ☐ YES ☐ NO

STUFFING BOX JACKET REQUIRED: ☐ YES ☐ NO

MECHANICAL SEAL REQUIRED: ☐ YES ☐ NO TYPE:

BEARING COOLING REQUIRED: ☐ YES ☐ NO

BY-PASS COOLING ORIFICE PLATES REQUIRED: ☐ YES ☐ NO

MATERIAL CODE	INTERNAL CLASSIFICATION
I - CAST IRON	1 IRON
B - BRONZE	2 BRONZE
S - STEEL	3 STAINLESS STEEL (TYPE)
D - DUCTILE IRON	4 STEEL
C - CHROME STEEL (11-13% CHROME)	5 DUCTILE IRON
SS- STAINLESS STEEL (TYPE)	6 CHROME STEEL
A - ALLOY	
h - HARDENED f - FACED	

EXTERNAL CASING MATERIAL ☐

INTERNAL CLASSIFICATION ☐

INTERNAL CLASSIFICATION IDENTIFICATION	1	2	3	4	5	6	7
IMPELLER	I	B	SS	S	I	C	
INNER CASE PARTS	I	I & B	SS	S	I	C	
SHAFT SLEEVES (PACKED TYPE)	Ch	Ch	SS	Af	Af	Af	
SHAFT SLEEVES (MECH. SEAL TYPE)	C	C	SS	C	C	C	
WEAR RINGS (IF REQUIRE)	I	B	SS	Ch	Ch	Ch	
SHAFT	S	S	SS	S	S	S	

SHOP TESTS	REQUIRED	WITNESSED
RUNNING PERFORMANCE		
NPSH		

REMARKS: Inst. HP = 400

09-4926

CHEMICAL CONSTRUCTION CORPORATION

CENTRIFUGAL PUMP - PROPOSAL DATA SHEET

SHEET OF

CLIENT AND LOCATION: High Sulfur Combustor Study

PLANT SECTION NAME AND SECTION NUMBER: Intermediate Chemical Product - S^o 100 T/D J-202

ISSUE RECORD: DATE / APPROVED BY / ISSUE / DATE / APPROVED BY / ISSUE

AUTHORIZATION NO.

LIQUID CHARACTERISTICS

LIQUID PUMPED: Magnesium Sulfite Slurry

SPECIFIC GRAVITY AT FLOW TEMPERATURE: 1.17

FLOW TEMPERATURE: 133 °F

VISCOSITY AT FLOW TEMPERATURE (CENTIPOISE) (SSU):

VAPOR PRESSURE AT FLOW TEMPERATURE: PSIA

PERCENT SOLIDS: 13 SIZE SOLIDS

CAPACITIES AND PRESSURES

GPM (US) AT FLOW TEMPERATURE: NORMAL DESIGN

DISCHARGE PRESSURE: PSIG

SUCTION PRESSURE AT PUMP AT FLOW RATE: PSIG

DIFFERENTIAL PRESSURE: PSI

DIFFERENTIAL HEAD (FEET OF LIQUID PUMPED): 175 FEET

NPSH AVAILABLE (CENTER LINE OF IMPELLER): FEET

DRIVER

INTEGRAL OR COUPLED SHAFT:

TYPE DRIVER: ☒ MOTOR ☐ TURBINE

DRIVER TO BE FURNISHED BY:

DRIVER TO BE MOUNTED BY:

CONSTRUCTION REQUIREMENTS

CASING TYPE: ☐ HORIZONTAL SPLIT ☐ VERTICAL SPLIT ☐ BARREL

CASING SUPPORT: ☐ FOOT ☐ VERTICAL ☐ CENTERLINE ☐ BRACKET

BASE PLATE REQUIRED: ☐ YES ☐ NO

EXTENDED FOR DRIVER: ☐ YES ☐ NO. DRAIN RIM REQUIRED: ☐ YES ☐ NO

COUPLING TYPE REQUIRED: GUARD REQUIRED: ☐ YES ☐ NO

STUFFING BOX PACKING REQUIRED: ☐ YES ☐ NO

STUFFING BOX JACKET REQUIRED: ☐ YES ☐ NO

MECHANICAL SEAL REQUIRED: ☐ YES ☐ NO TYPE:

BEARING COOLING REQUIRED: ☐ YES ☐ NO

BY-PASS COOLING ORIFICE PLATES REQUIRED: ☐ YES ☐ NO

MATERIAL CODE	INTERNAL CLASSIFICATION
I - CAST IRON	1 IRON
B - BRONZE	2 BRONZE
S - STEEL	3 STAINLESS STEEL (TYPE)
D - DUCTILE IRON	4 STEEL
C - CHROME STEEL (11-13% CHROME)	5 DUCTILE IRON
SS- STAINLESS STEEL (TYPE)	6 CHROME STEEL
A - ALLOY	
h - HARDENED f - FACED	

EXTERNAL CASING MATERIAL ☐

INTERNAL CLASSIFICATION ☐

INTERNAL CLASSIFICATION IDENTIFICATION	1	2	3	4	5	6	7.
IMPELLER	I	B	SS	S	I	C	
INNER CASE PARTS	I	I & B	SS	S	I	C	
SHAFT SLEEVES (PACKED TYPE)	Ch	Ch	SS	Af	Af	Af	
SHAFT SLEEVES (MECH. SEAL TYPE)	C	C	SS	C	C	C	
WEAR RINGS (IF REQUIRE)	I	B	SS	Ch	Ch	Ch	
SHAFT	S	S	SS	S	S	S	

SHOP TESTS	REQUIRED	WITNESSED
RUNNING PERFORMANCE		
NPSH		

REMARKS: Inst. HP = 400

PREPARED BY

DATE:

FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER SPECIFICATION AND AS NOTED HEREON

STD - SPA - 50

09 - 4926

CHEMICAL CONSTRUCTION CORPORATION
VESSEL DATA SHEET "A"

CLIENT AND LOCATION
High Sulfur Combustor Study

PLANT SECTION NAME AND SECTION NUMBER
Intermediate Chemical Product - S^o 100 T/D

Stack

ISSUE RECORD

DATE	APPROVED BY	ISSUE	DATE	APPROVED BY	ISSUE	DATE	APPROVED BY	ISSUE	DATE	APPROVED BY	ISSUE

DESIGN DATA

	CODE
SP. GR. – PRODUCT	CODE STAMP ☐ YES ☐ NO
WORKING PRESS. PSIG	STRESS RELIEVED
DESIGN PRESS PSIG	RADIOGRAPHED ☐ SPOT ☐ FULLY
WORKING TEMP 195 F	HAMMER TEST
DESIGN TEMP 600 F	WIND PRESSURE
JOINT EFFICIENCY %	**CORROSION ALLOWANCE**
HYDROSTATIC TEST	HEAD
EARTHQUAKE FACTOR	
	SHELL
ERECTION WEIGHT LB	INTERNAL PARTS
OPERATING WEIGHT LB	

WEIGHT OF VESSEL FILLED WITH LB

CONSTRUCTION

INSPECTION BY

TYPE OF PARTS AND MATERIAL SPECIFICATION

SHELL Brick-Lined Steel

HEAD

INTERNAL STEEL

EXTERNAL STEEL

INTERNAL PIPING

NOZZLE NECKS

NOZZLE FLANGES

MANHOLE – ☐ DAVIT ☐ HINGE

COUPLINGS

STUDS AND/OR BOLTS

NUTS

GASKETS

INSULATION SUPPORTS

INSULATION

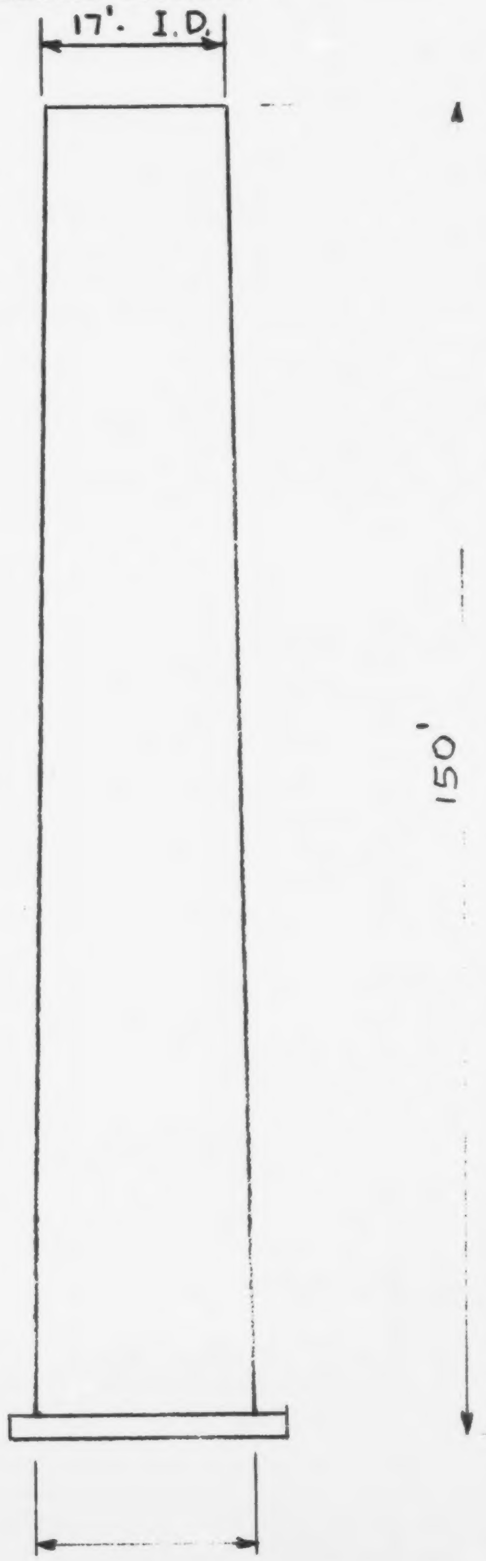
PAINT

① MEASURED FROM ℄ OF VESSEL TO FACE OF FLANGE

② VESSEL SUPPORTED ON ☐ STEEL ☐ CONCRETE ☐

③ VESSEL TOLERANCE – SEE STD. EF-1

④



NOZZLE DATA

NOZZLE	SIZE	ASA RATING	NOZZLE SCH	FLANGE TYPE	FLANGE FACE	DIM "A" ①	REMARKS
A 1							
A 2							
A 3							
A 4							
A 5							
A 6							
A 7							
A 8							
A 9							
A 10							
A 11							
A 12							

PREPARED BY: DATE:

FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION AND AS NOTED HEREON ☐

AUTHORIZATION NUMBER

REFERENCE NUMBER D-201

SHEET OF

CHEMICAL CONSTRUCTION CORPORATION

CLIENT AND LOCATION

PLANT SECTION NAME AND SECTION NUMBER

D-101

ISSUE RECORD

DATE
APPROVED BY
ISSUE
DATE
APPROVED BY
ISSUE
DATE
APPROVED BY
ISSUE
DATE
APPROVED BY
ISSUE

STAND-BY PACKAGE BOILER

Furnish ONE (1) Packaged Steam Generator in accordance with attached standard specification and this requisition and all attachments. Where conflicts exist between the standard specification and this requisition, the requisition shall govern.

The boiler will be installed and shall meet all local ordinances and regulations in addition to the Code requirements called for in the standard specification.

The unit shall be suitable for OUTDOOR installation.

The unit(s) shall be arranged with SUPERHEATER, ECONOMIZER, FORCED DRAFT FAN AND MOTOR DRIVE AND STACK.

Design conditions for each unit are as follows:

Maximum Continuous Capacity	31, 728 LB/HR
Normal Steam Flow	31, 728 LB/HR
Operating Pressure at Superheater Outlet	515 psig
Total Temperature at Superheater Outlet	675 ° F *
Feedwater Temperature	250 ° F
Continuous Blowdown	5 %
Efficiency of Unit (Minimum)	83 % HHV
Ambient Air Temperature	80 ° F
Design Pressure (Minimum)	600 psig
Fuel	Natural Gas
High Heating Valve	1, 000 BTU/Cu Ft

Composition ____________________

* At 31, 728 LB steam/hr. Manufacturer to advise steam temperature at ________ LB steam/hr. Provide steam temperature cruve.

Burners and combustion controls shall be suitable for 10:1 turndown ratio.

Windload Design shall be based on 35 psf basic wind load.

Earthquake design shall be based on zone O per the Uniform Building Code.

PREPARED BY:
DATE:
FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION
☐ AND AS NOTED HEREON
AUTHORIZATION NUMBER
REFERENCE NUMBER
SHEET OF

CLIENT AND LOCATION
SULFUR PLANT
PLANT SECTION NAME AND SECTION NUMBER
CALCINER SECTION D102

INERT GAS GENERATOR

ISSUE RECORD

DATE
APPROVED BY
ISSUE
DATE
APPROVED BY
ISSUE
DATE
APPROVED BY
ISSUE
DATE
APPROVED BY
ISSUE

PERFORMANCE

The System shall be designed to produce 7,932 SCFH of Gas, having less than 0.5% O_2 and minimum CO, at 100 PSIG and 95° F from a Fuel Gas of the following composition:

Component	% By Volume
C_1H_4	96
N_2	3.2
CO_2	0.8

Mol weight = 16.61
Gross Heating Value 967 BTU/Cuft Net Heating Value 873 BTU/Cuft
Available Gas Pressure = 100 PSIG.

Unit will be installed in a shed with the temperature maintained above 60° F.

Air temperature will vary from 0° F up to 100° F with an average relative humidity of 30%. Barometer 14.4 psia.

DESCRIPTION

Generator shall produce 7,932 SCFH of inert Gas at 100 psig, 95° F Dewpoint. Cooling water available at 85° F. System is to be completely piped and wired and assembled on a single base plate.

A. INERT GAS GENERATOR

The Gas Generator shall consist of a minimum of:

1. Adjustable Air-Fuel Mixer
2. Gas Blower
3. Combustion Chamber, Refactory lined as required, Water Jacketed, containing a Replaceable tip burner, Pilot Burner with spark ignition and electronic flame failure cut-out.

PREPARED BY: DATE: AUTHORIZATION NUMBER REFERENCE NUMBER
FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION
☐ AND AS NOTED HEREON
SHEET OF

INERT GAS GENERATOR

4. Heat Exchangers - Shell and Tube type with Removable bundles.
5. Two Separators with Traps for the automatic removal of moisture.
6. Orifice type flow meter, direct reading at compressor inlet.
7. Inlet Air Filter - Dry type with weather Hood.

B. COMPRESSION

Electric motor driven, non-lubricated reciprocating compressor complete with after cooler, separator and trap.

C. DRYER

NONE

CHEMICAL CONSTRUCTION CORPORATION
EXCHANGER DATA

DATE
APPROVED BY
ISSUE
DATE
APPROVED BY
ISSUE
DATE
APPROVED BY
ISSUE
DATE
APPROVED BY
ISSUE

CLIENT AND LOCATION

PLANT SECTION NAME AND SECTION NUMBER
Calciner Sect. 100

1 SERVICE OF UNIT: Gas Cooler ITEM NO. E103
2 SIZE: * 44 156 (4) TYPE: *
3 SURFACE PER UNIT: * 2,843 Ft.^{2} SHELLS PER UNIT: * 1 SURFACE PER SHELL: * 2,843 FT^2
4 NO. OF UNITS: 1 SHELL ARRANGEMENT: * POSITION: Horizontal

5 PERFORMANCE OF ONE UNIT

No.			Units	SHELL SIDE	TUBE SIDE
6				SHELL SIDE	TUBE SIDE
7	FLUID CIRCULATED			BFW - Deionized	Calciner Off Gas
8	TOTAL FLUID ENTERING		LB/HR	70,753	92,075
9		VAPOR	LB/HR		
10		LIQUID	LB/HR	70,753	
11		STEAM	LB/HR		
12		NON-CONDENSABLES	LB/HR		92,075
13	FLUID VAPORIZED OR CONDENSED		LB/HR		
14	STEAM CONDENSED		LB/HR		
15	LIQUID	S.G. 60°F/60°F	°API@60°F	0.978	
16		VISCOSITY	CENTIPOISES	0.406 160° F	
17		SPECIFIC HEAT	BTU/LB °F	1.0	
18		TH. COND.	BTU/HR °F FT²/FT.	0.383	

No.			Units	SHELL SIDE N.C. GAS	SHELL SIDE VAPOR	TUBE SIDE N.C. GAS	TUBE SIDE VAPOR
19	N.C. GAS OR VAPOR	MOLECULAR WEIGHT				32.7	
20		VISCOSITY	CENTIPOISES			0.0191	
21		SPECIFIC HEAT	BTU/LB °F			0.2386@235° F	
22		TH. COND.	BTU/HR °F FT²/FT.			2.0151	

No.		Units	SHELL SIDE	TUBE SIDE
23	LATENT HEAT OF VAPORIZATION	BTU/LB		
24	ENTHALPY	BTU/LB		
25	TEMPERATURE-IN	°F	140	350
26	TEMPERATURE-OUT	°F	180	170
27	OPERATING PRESSURE	PSIA. PSIG	65	13.2
28	NUMBER OF PASSES	PER SHELL	1	1
29	VELOCITY	FT/SEC.	*	*
30	MAX. ALLOWABLE PRESSURE DROP	PSI		
31	FOULING RESISTANCE			

32 HEAT EXCHANGED - BTU/HR 2.84×10^6 MTD CORRECTED * 65
33 TRANSFER RATE - SERVICE *

34 CONSTRUCTION OF EACH SHELL

No.		Units	SHELL SIDE	TUBE SIDE
35	DESIGN PRESSURE	PSI		
36	TEST PRESSURE	PSI	*	*
37	DESIGN TEMPERATURE	°F		

38 TUBES: NO: * OD: BWG: LENGTH: PITCH: △□◇
39 SHELL: ID: * OD: * SHELL COVER: *
40 CHANNEL AND COVER: * TUBE SHEETS: * FLOATING HEAD COVER: *
41 BAFFLES: * BAFFLE PITCH: * % CUT: *
42 GASKETS: CHANNEL COVER: CHANNEL TUBE SHEET: SHELL TUBE SHEET:
43 SHELL COVER: FLOATING HEAD:
44 CONNECTIONS-SHELL IN: OUT: SERIES: FACING:
45 CONNECTIONS-CHANNEL IN: OUT: SERIES: FACING:
46 OTHER CONNECTIONS-SHELL: CHANNEL:
47 CORROSION ALLOWANCE-SHELL SIDE: TUBE SIDE:
48 CODE REQUIREMENTS: ASME - UPV TEMA CLASS:
49
50
51
52
53

ISSUE

PREPARED BY: DATE:
FURNISH IN ACCORDANCE WITH BUYERS'S PURCHASE ORDER AND SPECIFICATION
☐ STD - SPC - 29 ☐ AND AS NOTED HEREON

AUTHORIZATION NUMBER

REFERENCE NUMBER
E-103
SHEET OF

* DATA TO BE FILLED IN BY SELLER

04-4456 REV. 2

CHEMICAL CONSTRUCTION CORPORATION
EXCHANGER DATA

CLIENT AND LOCATION

PLANT SECTION NAME AND SECTION NUMBER
CALCINER SECTION 100

1 SERVICE OF UNIT: HOT WATER COOLER ITEM NO. E-104
2 SIZE:* 10.7" x 168" TYPE:*
3 SURFACE PER UNIT:* (FT^2) (EFF) SHELLS PER UNIT:* ONE SURFACE PER SHELL:* 267 FT^2
4 NO. OF UNITS: 1 SHELL ARRANGEMENT:* POSITION:

5	PERFORMANCE OF ONE UNIT			
6			SHELL SIDE	TUBE SIDE
7	FLUID CIRCULATED		B.F.W. - Deionized	Cooling Water
8	TOTAL FLUID ENTERING	LB/HR	70,753	141,507
9	VAPOR	LB/HR		
10	LIQUID	LB/HR	70,753	141,507
11	STEAM	LB/HR		
12	NON-CONDENSABLES	LB/HR		
13	FLUID VAPORIZED OR CONDENSED	LB/HR		
14	STEAM CONDENSED	LB/HR		
15	LIQUID S.G. 60°F/60°F	°API@60°F	p = 61.0 (#/FT^3)	p = 62.1 (#FT^3)
16	LIQUID VISCOSITY	CENTIPOISES	0.4 At	0.75 At
17	LIQUID SPECIFIC HEAT	BTU/LB °F	1.0 160 (°F)	1.0 95. (°F)
18	LIQUID TH. COND.	BTU/HR °F FT^2/FT.	0.384	0.360
19	N.C. GAS OR VAPOR MOLECULAR WEIGHT		N.C. GAS / VAPOR	N.C. GAS / VAPOR
20	N.C. GAS OR VAPOR VISCOSITY	CENTIPOISES		
21	N.C. GAS OR VAPOR SPECIFIC HEAT	BTU/LB °F		
22	N.C. GAS OR VAPOR TH. COND.	BTU/HR °F FT^2/FT.		
23	LATENT HEAT OF VAPORIZATION	BTU/LB		
24	ENTHALPY	BTU/LB		
25	TEMPERATURE-IN	°F	180.	85.
26	TEMPERATURE-OUT	°F	140.	105.
27	OPERATING PRESSURE	PSIA. PSIG	30.	50.
28	NUMBER OF PASSES	PER SHELL	1.	2.
29	VELOCITY	FT/SEC.	*	*
30	MAX. ALLOWABLE PRESSURE DROP	PSI		
31	FOULING RESISTANCE			

32 HEAT EXCHANGED - BTU/HR 2,840,000 YES MTD [CORRECTED]* 62.4 (°F)
33 TRANSFER RATE - SERVICE*
34 CONSTRUCTION OF EACH SHELL

35	DESIGN PRESSURE	PSI		
36	TEST PRESSURE	PSI	*	*
37	DESIGN TEMPERATURE	°F		

38 TUBES: NO:* OD: BWG: LENGTH: PITCH: △□◇
39 SHELL: ID:* OD:* SHELL COVER:*
40 CHANNEL AND COVER:* TUBE SHEETS:* FLOATING HEAD COVER:*
41 BAFFLES:* BAFFLE PITCH:* % CUT:*
42 GASKETS: CHANNEL COVER: CHANNEL TUBE SHEET: SHELL TUBE SHEET:
43 SHELL COVER: FLOATING HEAD:
44 CONNECTIONS-SHELL IN: OUT: SERIES: FACING:
45 CONNECTIONS-CHANNEL IN: OUT: SERIES: FACING:
46 OTHER CONNECTIONS-SHELL: CHANNEL:
47 CORROSION ALLOWANCE-SHELL SIDE: TUBE SIDE:
48 CODE REQUIREMENTS: ASME - UPV TEMA CLASS:
49
50
51
52
53

PREPARED BY: DATE:
FURNISH IN ACCORDANCE WITH BUYERS'S PURCHASE ORDER AND SPECIFICATION AND AS NOTED HEREON
☐ STD - SPC - 29 ☐

AUTHORIZATION NUMBER

REFERENCE NUMBER
E104
SHEET OF

ISSUE RECORD: DATE / APPROVED BY / ISSUE

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04-4456 REV. 2

CHEMICAL CONSTRUCTION CORPORATION

ISSUE RECORD

DATE	APPROVED BY	ISSUE	DATE	APPROVED BY	ISSUE	DATE	APPROVED BY	ISSUE	DATE	APPROVED BY	ISSUE

CLIENT AND LOCATION

PLANT SECTION NAME AND SECTION NUMBER

E-201

REDUCTION WASTE HEAD BOILER

Furnish ONE (1) REDUCTION Waste Heat Boiler in accordance with attached standard specification for WASTE HEAT BOILER FIRETUBE TYPE and this requisition and all attachments. Where conflicts exist between the standard specification and this requisition, the requisition shall govern. The boiler will be installed and shall meet all local ordinances and regulations in addition to the code requirements called for in the standard specification.

DESIGN CONDITIONS: (For Each Unit)

1.	Rating		100%
2.	Steam Capacity		22, 527 LB/HR
3.	Operating Press at Boiler Outlet		550 PSIG
4.	Steam Temp. at Boiler Outlet		Sat. °F
5.	Feedwater Temperature		403 °F
6.	Continuous Blowdown		793 LB/HR
7.	Efficiency of Unit		97%
8.	Design Pressure (Water Side)		600 PSIG
9.	Elevation		Sea Level
10.	Waste Heat		Reduction Unit Off Gas
	a. Flow:	Dry Gas	LB/HR
		H_2O	LB/HR
		Total	110, 757 LB/HR
	b. Wet Gas Composition		H_2S=5. 8 % Vol. SO_2=1. 5 H_2O=26. 4 CO_2=12. 2 N_2= 52. 8 H_2=0. 8; CH_4=0. 03 Sulfur Vapor 0. 3
	c. Inlet Temperature		1316 °F
	d. Inlet Pressure		14. 6 PSIG
	e. Maximum Pressure Drop		1. 8 PSI
	f. Gas Side Design Pressure		25. 0 PSIG
	g. Gas Outlet Temperature		764 °F
	h. Heat Exchanged (given up by gas)		$19.27 \times 10^{+6}$ BTU/HR

i. Fouling Factor: Water Side __________ Gas Side __________

j. Corrosion Allowance: Water Side __________ Gas Side __________

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FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION ☐ AND AS NOTED HEREON			SHEET OF

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CHEMICAL CONSTRUCTION CORPORATION

EXCHANGER DATA

CLIENT AND LOCATION

PLANT SECTION NAME AND SECTION NUMBER

1	SERVICE OF UNIT:	ITEM NO. E301
2	SIZE: *	TYPE: *
3	SURFACE PER UNIT: *	SHELLS PER UNIT: * ONE SURFACE PER SHELL: *
4	NO. OF UNITS: ONE	SHELL ARRANGEMENT: * POSITION: Horizontal
5		PERFORMANCE OF ONE UNIT

			SHELL SIDE	TUBE SIDE
6			SHELL SIDE	TUBE SIDE
7	FLUID CIRCULATED		Steam	Cooling Water
8	TOTAL FLUID ENTERING	LB/HR	50,765	5,203 GPM
9	VAPOR	LB/HR		
10	LIQUID	LB/HR	34,901 15,864	5,203 GPM
11	STEAM	LB/HR		
12	NON-CONDENSABLES	LB/HR		
13	FLUID VAPORIZED OR CONDENSED	LB/HR		
14	STEAM CONDENSED	LB/HR	50,765	
15	LIQUID: S.G. 60°F/60°F	°API@60°F		
16	LIQUID: VISCOSITY	CENTIPOISES		
17	LIQUID: SPECIFIC HEAT	BTU/[LB][°F]		
18	LIQUID: TH. COND.	BTU/[HR][°F][FT²]/FT.		

			SHELL SIDE N.C. GAS	SHELL SIDE VAPOR	TUBE SIDE N.C. GAS	TUBE SIDE VAPOR
19	N.C. GAS OR VAPOR: MOLECULAR WEIGHT					
20	N.C. GAS OR VAPOR: VISCOSITY	CENTIPOISES				
21	N.C. GAS OR VAPOR: SPECIFIC HEAT	BTU/[LB][°F]				
22	N.C. GAS OR VAPOR: TH. COND.	BTU/[HR][°F][FT²]/FT.				

			SHELL SIDE	TUBE SIDE
23	LATENT HEAT OF VAPORIZATION	BTU/LB		
24	ENTHALPY	BTU/LB	(1) 1060 (2) 1172	
25	TEMPERATURE-IN	°F	(1) 130 (2) 275	85
26	TEMPERATURE-OUT	°F	130	105
27	OPERATING PRESSURE	PSIA. PSIG	4.0" HGA	100 PSIG
28	NUMBER OF PASSES	PER SHELL	ONE	
29	VELOCITY	FT/SEC.	*	*
30	MAX. ALLOWABLE PRESSURE DROP	PSI		
31	FOULING RESISTANCE			
32	HEAT EXCHANGED – BTU/HR		52,034,000 BTU/HR	MTD [CORRECTED] *
33	TRANSFER RATE – SERVICE *			
34			CONSTRUCTION OF EACH SHELL	
35	DESIGN PRESSURE	PSI		
36	TEST PRESSURE	PSI	*	*
37	DESIGN TEMPERATURE	°F		

38	TUBES:	NO: *	OD: BWG:	LENGTH:	PITCH: △□◇
39	SHELL:	ID: *	OD: *	SHELL COVER: *	
40	CHANNEL AND COVER: *		TUBE SHEETS: *	FLOATING HEAD COVER: *	
41	BAFFLES: *		BAFFLE PITCH: *	% CUT: *	
42	GASKETS: CHANNEL COVER:		CHANNEL TUBE SHEET:	SHELL TUBE SHEET:	
43	SHELL COVER:		FLOATING HEAD:		
44	CONNECTIONS–SHELL IN:		OUT:	SERIES:	FACING:
45	CONNECTIONS–CHANNEL IN:		OUT:	SERIES:	FACING:
46	OTHER CONNECTIONS–SHELL:			CHANNEL:	
47	CORROSION ALLOWANCE–SHELL SIDE:			TUBE SIDE:	
48	CODE REQUIREMENTS: ASME – UPV			TEMA CLASS:	
49					
50					
51					
52					
53					

PREPARED BY: DATE:	AUTHORIZATION NUMBER	REFERENCE NUMBER
FURNISH IN ACCORDANCE WITH BUYERS'S PURCHASE ORDER AND SPECIFICATION ☐ STD - SPC - 29 ☐ AND AS NOTED HEREON		SHEET OF

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04-4456 REV. 2

CHEMICAL CONSTRUCTION CORPORATION

EXCHANGER DATA

CLIENT AND LOCATION

PLANT SECTION NAME AND SECTION NUMBER CLAUS SECTION 500

1 SERVICE OF UNIT: CLAUS BOILER ITEM NO. E501

2 SIZE:* 47/62 - 84 TYPE:*

3 SURFACE PER UNIT:* 930 FT^2 SHELLS PER UNIT:* SURFACE PER SHELL:* 930 FT.

4 NO. OF UNITS: 1 SHELL ARRANGEMENT:* POSITION: Horizontal

5 PERFORMANCE OF ONE UNIT

No.			Unit	SHELL SIDE		TUBE SIDE	
6				SHELL SIDE		TUBE SIDE	
7	FLUID CIRCULATED			B. F. Water		Gas: Note (2)	
8	TOTAL FLUID ENTERING		LB/HR	6,409		125,484	
9	VAPOR		LB/HR				
10	LIQUID		LB/HR	6,402			
11	STEAM		LB/HR				
12	NON-CONDENSABLES		LB/HR			125,484	
13	FLUID VAPORIZED OR CONDENSED		LB/HR	6,219			
14	STEAM CONDENSED		LB/HR				
15	LIQUID	S.G. 60°F/60°F	*API@60°F	0.92			
16	LIQUID	VISCOSITY	CENTIPOISES	0.17 @287° F			
17	LIQUID	SPECIFIC HEAT	BTU/[LB][°F]	1.1			
18	LIQUID	TH. COND.	BTU/[HR][°F][FT^2]/FT.	0.375			
19	N.C. GAS OR VAPOR	MOLECULAR WEIGHT		N.C. GAS	VAPOR 18	N.C. GAS 28.7	VAPOR
20	N.C. GAS OR VAPOR	VISCOSITY	CENTIPOISES		0.016	0.027	
21	N.C. GAS OR VAPOR	SPECIFIC HEAT	BTU/[LB][°F]		0.45 @324° F	0.305 @665° F	
22	N.C. GAS OR VAPOR	TH. COND.	BTU/[HR][°F][FT^2]/FT.		0.016	0.026	
23	LATENT HEAT OF VAPORIZATION		BTU/LB	892			
24	ENTHALPY		BTU/LB				
25	TEMPERATURE-IN		°F	250		750	
26	TEMPERATURE-OUT		°F	324 (80lb. steam)		580	
27	OPERATING PRESSURE		PSIA, PSIG	80		10	
28	NUMBER OF PASSES		PER SHELL	1		1	
29	VELOCITY		FT/SEC.	*		*	
30	MAX. ALLOWABLE PRESSURE DROP		PSI				
31	FOULING RESISTANCE						

32 HEAT EXCHANGED - BTU/HR 6.20 x 106 x 10° MTD [CORRECTED]* 340 (WTD)

33 TRANSFER RATE - SERVICE* 19.6

34 CONSTRUCTION OF EACH SHELL

No.		Unit	SHELL SIDE	TUBE SIDE
35	DESIGN PRESSURE	PSI		
36	TEST PRESSURE	PSI	*	*
37	DESIGN TEMPERATURE	°F		

38 TUBES: NO:* OD: BWG: LENGTH: PITCH: △□◇

39 SHELL: ID:* OD:* SHELL COVER:*

40 CHANNEL AND COVER:* TUBE SHEETS:* FLOATING HEAD COVER:*

41 BAFFLES:* BAFFLE PITCH:* % CUT:*

42 GASKETS: CHANNEL COVER: CHANNEL TUBE SHEET: SHELL TUBE SHEET:

43 SHELL COVER: FLOATING HEAD:

44 CONNECTIONS-SHELL IN: OUT: SERIES: FACING:

45 CONNECTIONS-CHANNEL IN: OUT: SERIES: FACING:

46 OTHER CONNECTIONS-SHELL: CHANNEL:

47 CORROSION ALLOWANCE-SHELL SIDE: TUBE SIDE:

48 CODE REQUIREMENTS: ASME - UPV TEMA CLASS:

49

50

51

52

53

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CHEMICAL CONSTRUCTION CORPORATION

EXCHANGER DATA

CLIENT AND LOCATION

PLANT SECTION NAME AND SECTION NUMBER
CLAUS SECTION 500

1 SERVICE OF UNIT: CLAUS REACTOR REHEATER ITEM NO. E502
2 SIZE: * 75 - 250" TYPE: *
3 SURFACE PER UNIT: * 4,215 FT^2 SHELLS PER UNIT: * 1 SURFACE PER SHELL: * 4315 FT^2
4 NO. OF UNITS: 1 SHELL ARRANGEMENT: * POSITION: Horizontal
5 PERFORMANCE OF ONE UNIT

6			SHELL SIDE		TUBE SIDE	
7	FLUID CIRCULATED		Gas: See (1)		Gas: See (2)	
8	TOTAL FLUID ENTERING	LB/HR	121,074		125,484	
9	VAPOR	LB/HR				
10	LIQUID	LB/HR	190 Sulfur			
11	STEAM	LB/HR				
12	NON-CONDENSABLES	LB/HR	120,884		125,484	
13	FLUID VAPORIZED OR CONDENSED	LB/HR	190 Sulfur			
14	STEAM CONDENSED	LB/HR				
15	LIQUID: S.G. 60°F/60°F	°API@60°F				
16	LIQUID: VISCOSITY	CENTIPOISES				
17	LIQUID: SPECIFIC HEAT	BTU/LB °F				
18	LIQUID: TH. COND.	BTU/HR °F FT²/FT.				
19	N.C. GAS OR VAPOR: MOLECULAR WEIGHT		N.C. GAS 28.0	VAPOR 256	N.C. GAS 28.7	VAPOR -
20	N.C. GAS OR VAPOR: VISCOSITY	CENTIPOISES	0.022		0.025	
21	N.C. GAS OR VAPOR: SPECIFIC HEAT	BTU/LB °F	0.296 @362°F		0.265 @512°F	
22	N.C. GAS OR VAPOR: TH. COND.	BTU/HR °F FT²/FT.	0.019		0.0235	
23	LATENT HEAT OF VAPORIZATION	BTU/LB				
24	ENTHALPY	BTU/LB				
25	TEMPERATURE-IN	°F	300		580	
26	TEMPERATURE-OUT	°F	425		445	
27	OPERATING PRESSURE	PSIA. PSIG	7.1		7.6	
28	NUMBER OF PASSES	PER SHELL	1		1	
29	VELOCITY	FT/SEC.	*		*	
30	MAX. ALLOWABLE PRESSURE DROP	PSI				
31	FOULING RESISTANCE					

32 HEAT EXCHANGED - BTU/HR 4,505,000 MTD [CORRECTED] * 150
33 TRANSFER RATE - SERVICE * 6.96 (Calculated U = 7.18)
34 CONSTRUCTION OF EACH SHELL

35	DESIGN PRESSURE	PSI		
36	TEST PRESSURE	PSI	*	*
37	DESIGN TEMPERATURE	°F		

38 TUBES: NO: * OD: BWG: LENGTH: PITCH: △□◇
39 SHELL: ID: * OD: * SHELL COVER: *
40 CHANNEL AND COVER: * TUBE SHEETS: * FLOATING HEAD COVER: *
41 BAFFLES: * BAFFLE PITCH: * % CUT: *
42 GASKETS: CHANNEL COVER: CHANNEL TUBE SHEET: SHELL TUBE SHEET:
43 SHELL COVER: FLOATING HEAD:
44 CONNECTIONS-SHELL IN: OUT: SERIES: FACING:
45 CONNECTIONS-CHANNEL IN: OUT: SERIES: FACING:
46 OTHER CONNECTIONS-SHELL: CHANNEL:
47 CORROSION ALLOWANCE-SHELL SIDE: TUBE SIDE:
48 CODE REQUIREMENTS: ASME - UPV TEMA CLASS:
49
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CHEMICAL CONSTRUCTION CORPORATION

EXCHANGER DATA

ISSUE RECORD — DATE / APPROVED BY / ISSUE

CLIENT AND LOCATION

PLANT SECTION NAME AND SECTION NUMBER
CLAUS SECTION 500

1 SERVICE OF UNIT: FIRST CLAUS CONDENSER — ITEM NO. E503
2 SIZE: * 63 — TYPE: *
3 SURFACE PER UNIT: * 5,105 sq. FT. — SHELLS PER UNIT: * 1 — SURFACE PER SHELL: * 5,105 sq FT.
4 NO. OF UNITS: ONE — SHELL ARRANGEMENT: * — POSITION: Horizontal
5 PARTIAL BUNDLE

PERFORMANCE OF ONE UNIT

6				SHELL SIDE		TUBE SIDE	
7		FLUID CIRCULATED		BFW to Steam		Gas: H_2S. SO_2. H_2O. N2 CO_2	
8		TOTAL FLUID ENTERING	LB/HR	5,552		125,484	
9		VAPOR	LB/HR			3,839 (Sulfur)	
10		LIQUID	LB/HR	5,552			
11		STEAM	LB/HR				
12		NON-CONDENSABLES	LB/HR			121,645	
13		FLUID VAPORIZED OR CONDENSED	LB/HR	5,552		3,839 (Sulfur)	
14		STEAM CONDENSED	LB/HR				
15	LIQUID	S.G. 60°F/60°F	°API@60°F	0.94			
16		VISCOSITY	CENTIPOISES	2.16 @ 265° F			
17		SPECIFIC HEAT	BTU/[LB][°F]	1.1			
18		TH. COND.	BTU/[HR][°F][FT²]/FT.	0.394			
19	N.C. GAS OR VAPOR	MOLECULAR WEIGHT		N.C. GAS	VAPOR 18	N.C. GAS 28.7	VAPOR 220
20		VISCOSITY	CENTIPOISES		0.015	0.022	
21		SPECIFIC HEAT	BTU/[LB][°F]		0.45 @281° F	0.25 @374° F	
22		TH. COND.	BTU/[HR][°F][FT²]/FT.		0.016	0.0215	
23		LATENT HEAT OF VAPORIZATION	BTU/LB				
24		ENTHALPY	BTU/LB				
25		TEMPERATURE-IN	°F	250		445	
26		TEMPERATURE-OUT	°F	281		303	
27		OPERATING PRESSURE	PSIA. PSIG	35		15	
28		NUMBER OF PASSES	PER SHELL	1		1	
29		VELOCITY	FT/SEC.	*		*	
30		MAX. ALLOWABLE PRESSURE DROP	PSI				
31		FOULING RESISTANCE					

32 HEAT EXCHANGED – BTU/HR 5,337,000 — MTD [CORRECTED] * 76.6 (WTD)
33 TRANSFER RATE – SERVICE * 13.6

34 CONSTRUCTION OF EACH SHELL

35	DESIGN PRESSURE	PSI		
36	TEST PRESSURE	PSI	*	*
37	DESIGN TEMPERATURE	°F		

38 TUBES: NO: * OD: BWG: LENGTH: PITCH: △☐◇
39 SHELL: ID: * OD: * SHELL COVER: *
40 CHANNEL AND COVER: * TUBE SHEETS: * FLOATING HEAD COVER: *
41 BAFFLES: * BAFFLE PITCH: * % CUT: *
42 GASKETS: CHANNEL COVER: CHANNEL TUBE SHEET: SHELL TUBE SHEET:
43 SHELL COVER: FLOATING HEAD:
44 CONNECTIONS–SHELL IN: OUT: SERIES: FACING:
45 CONNECTIONS–CHANNEL IN: OUT: SERIES: FACING:
46 OTHER CONNECTIONS–SHELL: CHANNEL:
47 CORROSION ALLOWANCE–SHELL SIDE: TUBE SIDE:
48 CODE REQUIREMENTS: ASME – UPV TEMA CLASS:
49
50
51
52
53

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04-4456 REV. 2

CHEMICAL CONSTRUCTION CORPORATION
EXCHANGER DATA

DATE		CLIENT AND LOCATION			
		PLANT SECTION NAME AND SECTION NUMBER	CLAUSS SECTION	500	
APPROVED BY	1	SERVICE OF UNIT: SECOND CLAUS CONDENSER		ITEM NO. E504	
	2	SIZE:* 63	TYPE:*		
	3	SURFACE PER UNIT:* 5,473 FT²	SHELLS PER UNIT:* 1	SURFACE PER SHELL:* 5,473 sq FT.	
	4	NO. OF UNITS: 1	SHELL ARRANGEMENT:* Parallel	POSITION: Horizontal	
	5	**PERFORMANCE OF ONE UNIT**			

	6			**SHELL SIDE**		**TUBE SIDE**	
	7	FLUID CIRCULATED		Water		Gas: H_2S0, SO_2, H_20,	
	8	TOTAL FLUID ENTERING	LB/HR	7,329		121,645	
ISSUE	9	VAPOR	LB/HR			5,838 Sulfur	
	10	LIQUID	LB/HR	7,329			
	11	STEAM	LB/HR				
DATE	12	NON-CONDENSABLES	LB/HR			115,807	
	13	FLUID VAPORIZED OR CONDENSED	LB/HR	7,107		5,838 Sulfur	
	14	STEAM CONDENSED	LB/HR				
APPROVED BY	15	LIQUID — S.G. 60°F/60°F	°API@60°F	0.927			
	16	LIQUID — VISCOSITY	CENTIPOISES	0.16 @ 281° F			
	17	LIQUID — SPECIFIC HEAT	BTU/[LB][°F]	1.03		/	
	18	LIQUID — TH. COND.	BTU/[HR][°F][FT²]/FT.	0.396			
	19	N.C. GAS OR VAPOR — MOLECULAR WEIGHT		N.C. GAS	VAPOR 18	N.C. GAS 28	VAPOR 220
	20	N.C. GAS OR VAPOR — VISCOSITY	CENTIPOISES		0.0157	0.022	
	21	N.C. GAS OR VAPOR — SPECIFIC HEAT	BTU/[LB][°F]		0.45 @281° F	0.289 @374° F	
	22	N.C. GAS OR VAPOR — TH. COND.	BTU/[HR][°F][FT²]/FT.		0.015	0.019	
	23	LATENT HEAT OF VAPORIZATION	BTU/LB				
ISSUE	24	ENTHALPY	BTU/LB				
	25	TEMPERATURE-IN	°F	250		484	
	26	TEMPERATURE-OUT	°F	281		304	
DATE	27	OPERATING PRESSURE	PSIA. PSIG	35		10	
	28	NUMBER OF PASSES	PER SHELL	1		1	
	29	VELOCITY	FT/SEC.	*		*	
APPROVED BY	30	MAX. ALLOWABLE PRESSURE DROP	PSI				
	31	FOULING RESISTANCE					
	32	HEAT EXCHANGED - BTU/HR 7.05×10^6		MTD [CORRECTED]* 82.9			
	33	TRANSFER RATE - SERVICE* 15.4					
	34	**CONSTRUCTION OF EACH SHELL**					
	35	DESIGN PRESSURE	PSI				
	36	TEST PRESSURE	PSI	*		*	
	37	DESIGN TEMPERATURE	°F				

	38	TUBES: NO:*	OD:	BWG:	LENGTH:	PITCH: △□◇
ISSUE	39	SHELL: ID:*		OD:*	SHELL COVER:*	
	40	CHANNEL AND COVER:*	TUBE SHEETS:*		FLOATING HEAD COVER:*	
	41	BAFFLES:*		BAFFLE PITCH:*		% CUT:*
DATE	42	GASKETS: CHANNEL COVER:	CHANNEL TUBE SHEET:		SHELL TUBE SHEET:	
	43	SHELL COVER:	FLOATING HEAD:			
	44	CONNECTIONS-SHELL IN:	OUT:		SERIES:	FACING:
APPROVED BY	45	CONNECTIONS-CHANNEL IN:	OUT:		SERIES:	FACING:
	46	OTHER CONNECTIONS-SHELL:			CHANNEL:	
	47	CORROSION ALLOWANCE-SHELL SIDE:			TUBE SIDE:	
	48	CODE REQUIREMENTS: ASME - UPV				TEMA CLASS:
	49					
	50					
	51					
	52					
	53					

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CHEMICAL CONSTRUCTION CORPORATION
EXCHANGER DATA

ISSUE RECORD

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PLANT SECTION NAME AND SECTION NUMBER
INCINERATOR SECTION

1 SERVICE OF UNIT: Combined Incinerator Preheater ITEM NO. E-601
2 SIZE:* 82 x 360 TYPE:*
3 SURFACE PER UNIT:* 8,884 sq. FT SHELLS PER UNIT:* 1 SURFACE PER SHELL:* 8,884
4 NO. OF UNITS: SHELL ARRANGEMENT:* POSITION: Horizontal
5 PERFORMANCE OF ONE UNIT

No.		Item	Unit	Shell Side		Tube Side	
6				SHELL SIDE		TUBE SIDE	
7		FLUID CIRCULATED		Claus Off - Gas		Incinerator Off - Gas	
8		TOTAL FLUID ENTERING	LB/HR	115,754		69,718	
9		VAPOR	LB/HR				
10		LIQUID	LB/HR				
11		STEAM	LB/HR				
12		NON-CONDENSABLES	LB/HR	115,754		69,718	
13		FLUID VAPORIZED OR CONDENSED	LB/HR				
14		STEAM CONDENSED	LB/HR				
15	LIQUID	S.G. 60°F/60°F	°API@60°F				
16		VISCOSITY	CENTIPOISES				
17		SPECIFIC HEAT	BTU/LB °F				
18		TH. COND. BTU/HR °F FT^2/FT.					
19	N.C. GAS OR VAPOR	MOLECULAR WEIGHT		N.C. GAS 26.9	VAPOR	N.C. GAS 27.4	VAPOR
20		VISCOSITY	CENTIPOISES	.025		.03	
21		SPECIFIC HEAT	BTU/LB °F	.30		.32	
22		TH. COND. BTU/HR °F FT^2/FT.		.022		.028	
23		LATENT HEAT OF VAPORIZATION	BTU/LB				
24		ENTHALPY	BTU/LB				
25		TEMPERATURE-IN	°F	300		1200	
26		TEMPERATURE-OUT	°F	740		500	
27		OPERATING PRESSURE	PSIA. PSIG	18.2		15.9	
28		NUMBER OF PASSES	PER SHELL	1		1	
29		VELOCITY	FT/SEC.	*		*	
30		MAX. ALLOWABLE PRESSURE DROP	PSI				
31		FOULING RESISTANCE					

32 HEAT EXCHANGED - BTU/HR 15,493,000 MTD [CORRECTED]* 314°F
33 TRANSFER RATE - SERVICE* 5.58
34 CONSTRUCTION OF EACH SHELL

No.	Item	Unit	Shell Side	Tube Side
35	DESIGN PRESSURE	PSI		
36	TEST PRESSURE	PSI	*	*
37	DESIGN TEMPERATURE	°F		

38 TUBES: NO:* OD: BWG: LENGTH: PITCH: △□◇
39 SHELL: ID:* OD:* SHELL COVER:*
40 CHANNEL AND COVER:* TUBE SHEETS:* FLOATING HEAD COVER:*
41 BAFFLES:* BAFFLE PITCH:* % CUT:*
42 GASKETS: CHANNEL COVER: CHANNEL TUBE SHEET: SHELL TUBE SHEET:
43 SHELL COVER: FLOATING HEAD:
44 CONNECTIONS-SHELL IN: OUT: SERIES: FACING:
45 CONNECTIONS-CHANNEL IN: OUT: SERIES: FACING:
46 OTHER CONNECTIONS-SHELL: CHANNEL:
47 CORROSION ALLOWANCE-SHELL SIDE: TUBE SIDE:
48 CODE REQUIREMENTS: ASME - UPV TEMA CLASS:
49
50
51
52
53

PREPARED BY: DATE: AUTHORIZATION NUMBER REFERENCE NUMBER
FURNISH IN ACCORDANCE WITH BUYERS'S PURCHASE ORDER AND SPECIFICATION
☐ STD - SPC - 29 ☐ AND AS NOTED HEREON
SHEET OF

* DATA TO BE FILLED IN BY SELLER

04-4456 REV.2

CHEMICAL CONSTRUCTION CORPORATION
VESSEL DATA SHEET "A"

ISSUE RECORD

DATE | APPROVED BY | ISSUE | DATE | APPROVED BY | ISSUE | DATE | APPROVED BY | ISSUE | DATE | APPROVED BY | ISSUE

CLIENT AND LOCATION

PLANT SECTION NAME AND SECTION NUMBER

CALCINER SECTION 100

HOT WATER SURGE TANK G101

DESIGN DATA

Chemico std. SNA116.	**CODE**
SP. GR. – PRODUCT 1.0	**CODE STAMP** ☐ **YES** ☒ **NO**
WORKING PRESS. 3 **PSIG**	**STRESS RELIEVED** No
DESIGN PRESS 5 **PSIG**	**RADIOGRAPHED** ☒ **SPOT** ☐ **FULLY**
WORKING TEMP 140 **F**	**HAMMER TEST**
DESIGN TEMP 200 **F**	**WIND PRESSURE**
JOINT EFFICIENCY 70 **%**	**CORROSION ALLOWANCE**
HYDROSTATIC TEST	**HEAD**
EARTHQUAKE FACTOR	
	SHELL
ERECTION WEIGHT 6060 **LB**	**INTERNAL PARTS**
OPERATING WEIGHT **LB**	

WEIGHT OF VESSEL FILLED WITH water 34,800 **LB**

CONSTRUCTION (min.) Single Welded Butt Joint without Backing Strip.

INSPECTION BY Baker

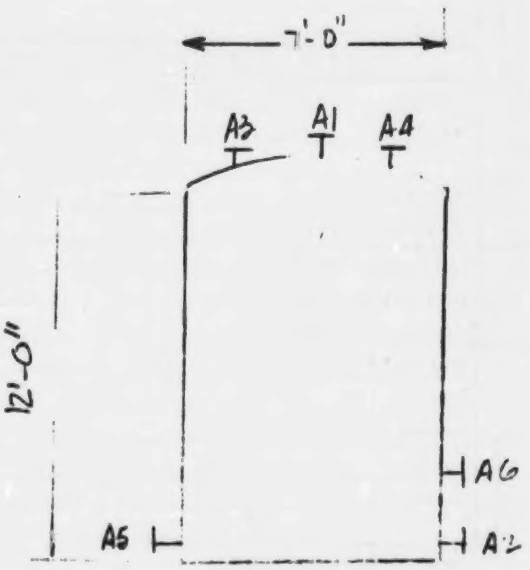
TYPE OF PARTS AND MATERIAL SPECIFICATION

SHELL	ASTM A-283 GrC
HEAD	ASTM A-283 GrC
Bott. Pl.	ASTM A-283 GrC
INTERNAL STEEL	
EXTERNAL STEEL	
INTERNAL PIPING	
NOZZLE NECKS	
NOZZLE FLANGES	
MANHOLE – ☐ **DAVIT** ☐ **HINGE**	
COUPLINGS	
STUDS AND/OR BOLTS	
NUTS	
GASKETS	
INSULATION SUPPORTS	
INSULATION	
PAINT	

NOZZLE DATA

NOZZLE	SIZE	ASA	NOZZLE	FLANGE		DIM "A"	REMARKS
		RATING	SCH	TYPE	FACE	①	
A 1		150	x 5	SO	RF		Inlet
A 2							Outlet
A 3							Make-up
A 4							Vent
A 5							Drain
A 6							Manhole
A 7							
A 8							
A 9							
A 10							
A 11							
A 12							

① MEASURED FROM ℄ OF VESSEL TO FACE OF FLANGE
② VESSEL SUPPORTED ON ☐ STEEL ☐ CONCRETE ☐
③ VESSEL TOLERANCE – SEE STD. EF-1
④



PREPARED BY: **DATE:**

FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION AND AS NOTED HEREON ☐

AUTHORIZATION NUMBER	**REFERENCE NUMBER**
	SHEET **OF**

04-4549

CHEMICAL CONSTRUCTION CORPORATION
VESSEL DATA SHEET "A"

ISSUE RECORD

DATE | APPROVED BY | ISSUE | DATE | APPROVED BY | ISSUE | DATE | APPROVED BY | ISSUE | DATE | APPROVED BY | ISSUE

CLIENT AND LOCATION: SULFUR PLANT

PLANT SECTION NAME AND SECTION NUMBER: CALCINER SECTION G-102 A, B

INERT GAS RECEIVERS 2(TWO) REQ'D

DESIGN DATA

	CODE ASME Sect VIII
SP. GR. – PRODUCT 0.006	CODE STAMP ☒ YES ☐ NO
WORKING PRESS. 100 PSIG	STRESS RELIEVED
DESIGN PRESS 150 PSIG	RADIOGRAPHED ☒ SPOT ☐ FULLY
WORKING TEMP 100 F	HAMMER TEST,
DESIGN TEMP 150 F	WIND PRESSURE
JOINT EFFICIENCY 85 %	**CORROSION ALLOWANCE**
HYDROSTATIC TEST Per Code	HEAD 1/8"
EARTHQUAKE FACTOR	
	SHELL 1/8"
ERECTION WEIGHT LB	INTERNAL PARTS
OPERATING WEIGHT 13000 LB	

WEIGHT OF VESSEL FILLED WITH water 78000 LB

CONSTRUCTION Double Welded Butt Joint

INSPECTION BY Buyer and Underwriter

① MEASURED FROM ℄ OF VESSEL TO FACE OF FLANGE

② VESSEL SUPPORTED ON ☐ STEEL ☐ CONCRETE ☐

③ VESSEL TOLERANCE – SEE STD. EF–;

④

TYPE OF PARTS AND MATERIAL SPECIFICATION

SHELL SA-285 Gr C FBQ & Note 5

HEAD SA-285 Gr C FBQ & Note 5

INTERNAL STEEL

EXTERNAL STEEL

INTERNAL PIPING

NOZZLE NECKS

NOZZLE FLANGES

MANHOLE – ☐ DAVIT ☐ HINGE

COUPLINGS

STUDS AND/OR BOLTS

NUTS

GASKETS

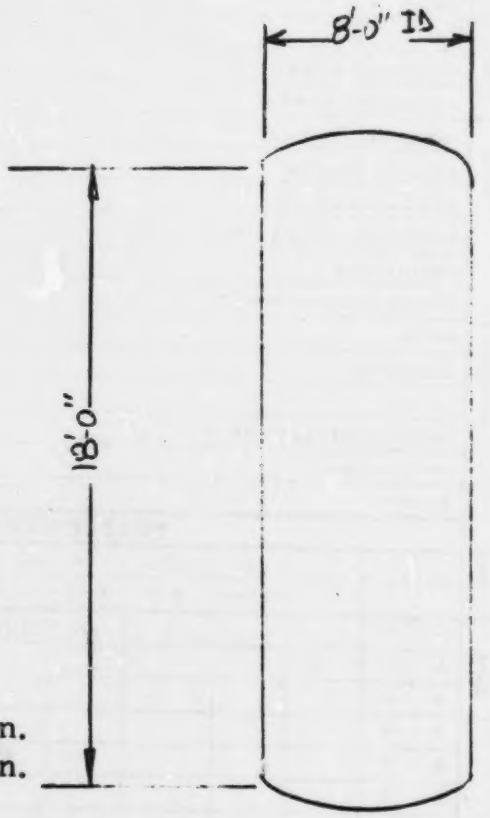
INSULATION SUPPORTS

INSULATION

PAINT

NOZZLE DATA

NOZZLE	SIZE	ASA RATING	NOZZLE SCH	FLANGE TYPE	FLANGE FACE	DIM "A" ①	REMARKS
A 1							Inlet
A 2							Outlet
A 3							Booth
A 4							Sight Glass Conn.
A 5							Sight Glass Conn.
A 6							Drain
A 7							Relief Valve
A 8							Manhole W/Cover
A 9							
A 10							
A 11							
A 12							



PREPARED BY: DATE:

FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION ☐ AND AS NOTED HEREON

AUTHORIZATION NUMBER

REFERENCE NUMBER

SHEET OF

CHEMICAL CONSTRUCTION CORPORATION
HORIZONTAL OR VERTICAL PROCESS TANKS

ISSUE RECORD

CLIENT AND LOCATION	PREPARED BY — DATE
PLANT SECTION NAME AND SECTION NUMBER	CHECKED BY — DATE
NAME OF UNIT: L.P. WASTE HEAT BOILER BLOWDOWN TANK — UNITS REQUIRED: ONE G103	APPROVED BY — DATE

DESIGN DATA ASME Sect. VIII

BUYER'S SPEC.	Std. SNA 34.5	CODE	and Note ⑦
SP. GR. PRODUCT	1.0	CODE STAMP	☒ YES ☐ NO
DESIGN PRESS.	2.5 PSIG	STRESS RELIEVED	NO
WORKING PRESS.	5 PSIG	RADIOGRAPHED	☒ SPOT ☐ FULLY
DESIGN TEMP.	267° F	EARTHQUAKE FACTOR	
WORKING TEMP.	228° F	WIND PRESS.	
JOINT EFFICIENCY	85%	**CORROSION ALLOWANCE**	
HYDROSTATIC TEST	Per Code	HEAD	1/8
NATIONAL BOARD STAMP	☐ YES ☐ NO	SHELL	1/8
ERECTION WEIGHT	1670	INT'L FIXED PARTS	PER SIDE
OPERATING WEIGHT	2270	INT'L REMOVABLE PARTS	TOTAL

WEIGHT OF TOWER FILLED WITH Water 2610

CONSTRUCTION Double Welded Butt Joint

INSPECTION BY ☒ BUYER ☒ UNDERWRITER ☐ CLIENT ☐

TYPE OF PARTS AND MATERIAL SPECIFICATION

Pipe	SA-106 GR B
Cap	SA-181 GR I or SA-285 GR C
INTERNAL STEEL	SA-283 GR C
EXTERNAL STEEL	SA-283 GR C
INTERNAL PIPING	
NOZZLE NECKS	
NOZZLE FLANGE	
MANHOLE NOZZLE	
MANHOLE FLANGE	
MANHOLE COVERS	
COUPLINGS	
GASKETS	
BOLTS	STUDS
NUTS	
INSULATION SUPPORTS	
INSULATION	
PAINT	

NOTES

① MEASURED FROM ℄ OF VESSEL TO FACE OF FLANGE

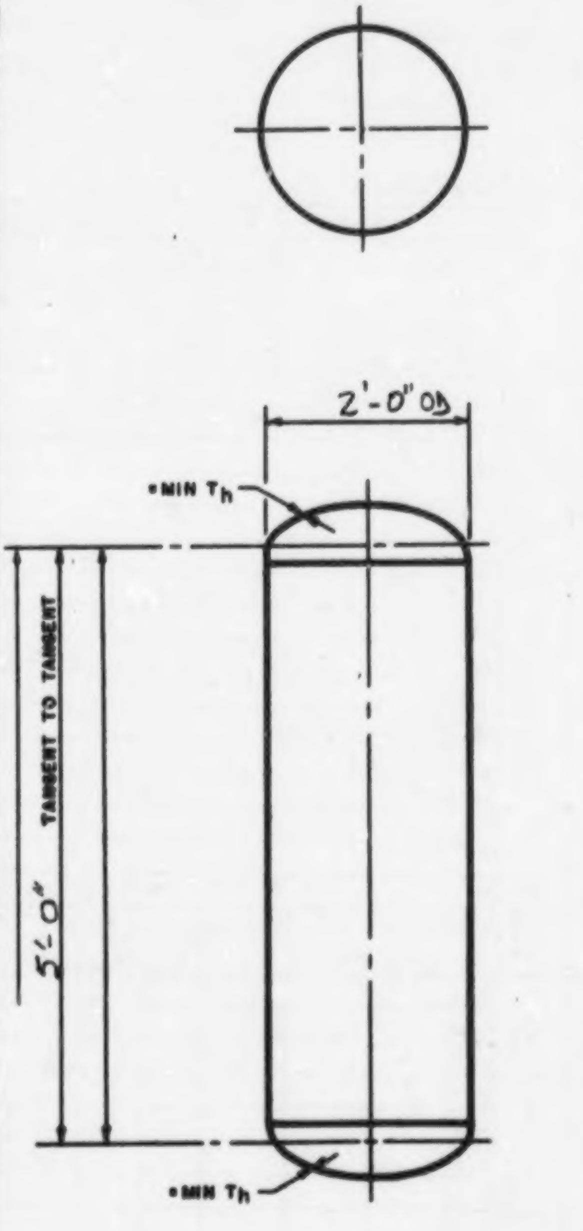
② TANK WILL SET ON ☐ STEEL; ☐ CONCRETE; ☐

③ VESSEL TOLERANCES: SEE STD. EF-1

④ MANHOLE ☐ DAVIT ☐ HINGED

⑤ ORIENTATION BY ______

⑥ SELLER TO QUOTE UNIT PRICES OF NOZZLES 2 INCH THROUGH 24 INCH SIZES



NOZZLE DATA

NOZZLE NO. AND SIZE	ASA RATING	NOZZLE SCH'D.	FLANGE TYPE	FLANGE FACE	DIM. "A" ①	REMARKS
N 1						Inlet Blowoff
N 2						Outlet Blowoff
N 3						Vent
N 4						Drain
N 5						Cooling Water
N 6						Manhole w/Cover
N 7						Pressure Gauge
N 8						Level Gauge (2)
N 9						Temp. Indicator
N10						
N11						
N12						

FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION
☐ STD-SNA-34 ☐
☐ STD-SNA-116 ☐
AND AS NOTED HEREON

AUTHORIZATION NUMBER

REFERENCE NUMBER

SHEET OF

CHEMICAL CONSTRUCTION CORPORATION
HORIZONTAL OR VERTICAL PROCESS TANKS

ISSUE RECORD

CLIENT AND LOCATION

PREPARED BY DATE

PLANT SECTION NAME AND SECTION NUMBER Package Boiler
Waste Heat Boiler E-101

CHECKED BY DATE

NAME OF UNIT
BLOWDOWN TANKS FOR Waste Heat Boiler E-201

UNITS REQUIRED Three(3)

APPROVED BY DATE

DESIGN DATA

BUYER'S SPEC. STD. SRA 34.5
CODE ASME Sect. VIII and Note ⑦
SP. GR. PRODUCT 1.0
CODE STAMP ☒ YES ☐ NO
DESIGN PRESS. 160 PSIG
STRESS RELIEVED No
WORKING PRESS. 5 PSIG
RADIOGRAPHED ☒ SPOT ☐ FULLY
DESIGN TEMP. 370° F
EARTHQUAKE FACTOR
WORKING TEMP. 226° F
WIND PRESS.
JOINT EFFICIENCY 85%
HYDROSTATIC TEST Per Code

CORROSION ALLOWANCE

HEAD 1/8
SHELL 1/8
INT'L FIXED PARTS PER SIDE
INT'L REMOVABLE PARTS TOTAL

NATIONAL BOARD STAMP ☐ YES ☐ NO
ERECTION WEIGHT 1460#
OPERATING WEIGHT 1900#
WEIGHT OF TOWER FILLED WITH Water 2130#
CONSTRUCTION Double Welded Butt Joint

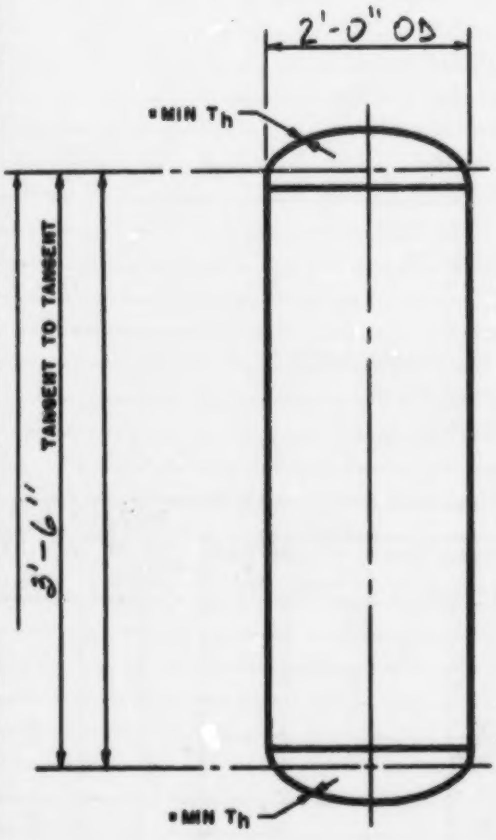
INSPECTION BY ☒ BUYER ☒ UNDERWRITER ☐ CLIENT ☐

TYPE OF PARTS AND MATERIAL SPECIFICATION

Pipe SA-106 GR B
Cap SA-181 GR I or SA 285 GR C
INTERNAL STEEL SA 283 GR C
EXTERNAL STEEL SA 283 GR C
INTERNAL PIPING
NOZZLE NECKS
NOZZLE FLANGE
MANHOLE NOZZLE
MANHOLE FLANGE
MANHOLE COVERS
COUPLINGS
GASKETS
BOLTS
STUDS
NUTS
INSULATION SUPPORTS
INSULATION
PAINT

NOTES

① MEASURED FROM ℄ OF VESSEL TO FACE OF FLANGE
② TANK WILL SET ON ☐ STEEL; ☐ CONCRETE; ☐
③ VESSEL TOLERANCES: SEE STD. EF-1
④ MANHOLE ☐ DAVIT ☐ HINGED
⑤ ORIENTATION BY ______
⑥ SELLER TO QUOTE UNIT PRICES OF NOZZLES 2 INCH THROUGH 24 INCH SIZES



NOZZLE DATA

NOZZLE NO. AND SIZE		ASA RATING	NOZZLE SCH'D.	FLANGE TYPE	FLANGE FACE	DIM. "A" ①	REMARKS
N 1							Inlet Blowoff
N 2							Outlet Blowoff
N 3							Vent
N 4							Draw
N 5							Cooling Water
N 6							Manhole w/Cover
N 7							Pressure Gauge
N 8							Level Gauge (2)
N 9							Temp. Indicator
N10							
N11							
N12							

FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION
☐ STD-SNA-34 ☐
☐ STD-SNA-116 ☐
AND AS NOTED HEREON

AUTHORIZATION NUMBER

REFERENCE NUMBER G104

SHEET OF

04-4544

CHEMICAL CONSTRUCTION CORPORATION

ISSUE RECORD

DATE	APPROVED BY	ISSUE	DATE	APPROVED BY	ISSUE	DATE	APPROVED BY	ISSUE	DATE	APPROVED BY	ISSUE

CLIENT AND LOCATION

PLANT SECTION NAME AND SECTION NUMBER

G-301

DEAERATOR - STEAM CONDENSER

ITEM NUMBER	G-301
QUANTITY	One
TYPE	Spray Tray
VENT CONDENSER	Internal W/Stainless Steel Tubes
OUTLET CAPACITY (Lbs/HR)	79,000 Design Normal
CONDENSATE RETURN	63,000
@ 125 °F	42,600 LBS/HR
@ 70° F	12,280 LBS/HR
MAKE-UP	
@ 70° F	As Required
STEAM - 30 PSIG	370° F and 7,700 LBS/HR
SOURCE OF MAKE-UP	
Treated	
PRESSURE (PSIG)	
Operating	15 PSIG
Design	50 PSIG
TEMPERATURE (° F)	
Operating	250° F
Design	400° F

PREPARED BY: DATE:

FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION

☐ AND AS NOTED HEREON

AUTHORIZATION NUMBER

REFERENCE NUMBER

SHEET OF

04 - 4551 REV. 1

CHEMICAL CONSTRUCTION CORPORATION
VESSEL DATA SHEET "A"

CLIENT AND LOCATION	D-[illegible]0[illegible]3
PLANT SECTION NAME AND SECTION NUMBER CLAUS SECTION 500	
FIRST & SECOND CLAUS SEPARATORS G-501 A&B	

ISSUE RECORD

DESIGN DATA

		CODE	API-620&Asme IV
SP. GR. – PRODUCT		CODE STAMP ☐ YES ☐ NO	
WORKING PRESS.	9 PSIG	STRESS RELIEVED	No
DESIGN PRESS	15 PSIG	RADIOGRAPHED ☐ SPOT ☐ FULLY	
WORKING TEMP	305° F	HAMMER TEST	
DESIGN TEMP	335° F	WIND PRESSURE	
JOINT EFFICIENCY	70 %	**CORROSION ALLOWANCE**	
HYDROSTATIC TEST		HEAD	1/8"
EARTHQUAKE FACTOR			
		SHELL	1/8"
ERECTION WEIGHT	21, 600 LB	INTERNAL PARTS	1/8" Total
OPERATING WEIGHT	58, 500 LB		

WEIGHT OF VESSEL FILLED WITH	LB
CONSTRUCTION	Single Welded Putt Joints w/No Backing Strip (minimum)
INSPECTION BY	

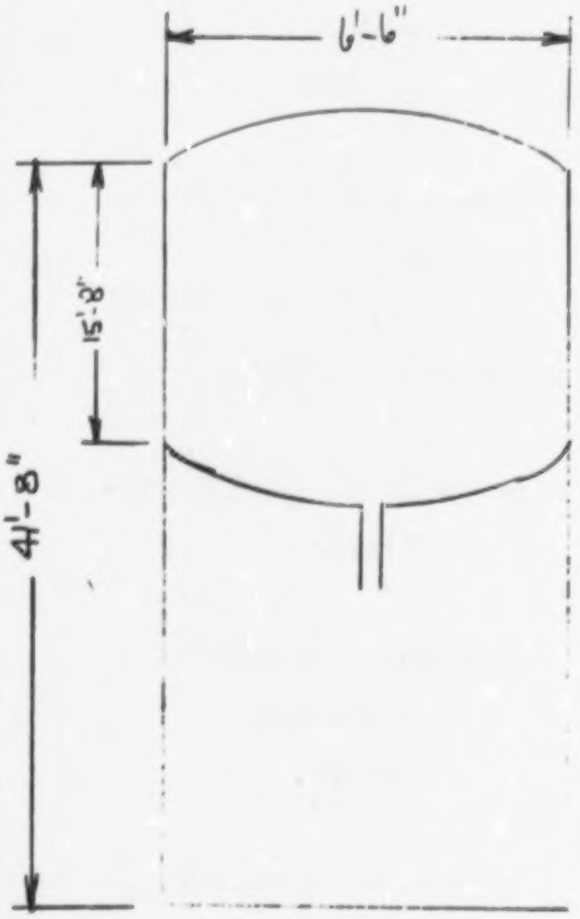
TYPE OF PARTS AND MATERIAL SPECIFICATION

SHELL	SA 285 GRC
HEAD	Roof SA 285 GRC
	Internal Head and Bottom Plate SA285GRC
INTERNAL STEEL	
EXTERNAL STEEL	
INTERNAL PIPING	
NOZZLE NECKS	
NOZZLE FLANGES	
MANHOLE – ☐ DAVIT ☐ HINGE	
COUPLINGS	
STUDS AND/OR BOLTS	
NUTS	
GASKETS	
INSULATION SUPPORTS	
INSULATION	
PAINT	

NOZZLE DATA

NOZZLE	SIZE	ASA RATING	NOZZLE SCH	FLANGE TYPE	FLANGE FACE	DIM "A" ①	REMARKS
A 1							
A 2							
A 3							
A 4							
A 5							
A 6							
A 7							
A 8							
A 9							
A 10							
A 11							
A 12							

① MEASURED FROM ℄ OF VESSEL TO FACE OF FLANGE
② VESSEL SUPPORTED ON ☐ STEEL ☐ CONCRETE ☐
③ VESSEL TOLERANCE – SEE STD. EF-1
④



PREPARED BY: DATE:	AUTHORIZATION NUMBER	REFERENCE NUMBER
FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION ☐ AND AS NOTED HEREON		SHEET OF

04-4549

CHEMICAL CONSTRUCTION CORPORATION
VESSEL DATA SHEET "A"

ISSUE RECORD

DATE	APPROVED BY	ISSUE
DATE	APPROVED BY	ISSUE
DATE	APPROVED BY	ISSUE
DATE	APPROVED BY	ISSUE

CLIENT AND LOCATION

PLANT SECTION NAME AND SECTION NUMBER
REDUCTION SECTION

REDUCTION REACTOR H-201

DESIGN DATA

	CODE
SP. GR. – PRODUCT	CODE STAMP ☐ YES ☐ NO
WORKING PRESS. PSIG	STRESS RELIEVED
DESIGN PRESS PSIG	RADIOGRAPHED ☐ SPOT ☐ FULLY
WORKING TEMP F	HAMMER TEST
DESIGN TEMP F	WIND PRESSURE
JOINT EFFICIENCY %	**CORROSION ALLOWANCE**
HYDROSTATIC TEST	HEAD
EARTHQUAKE FACTOR	
	SHELL
ERECTION WEIGHT LB	INTERNAL PARTS
OPERATING WEIGHT LB	

WEIGHT OF VESSEL FILLED WITH LB

CONSTRUCTION

INSPECTION BY

① MEASURED FROM ℄ OF VESSEL TO FACE OF FLANGE
② VESSEL SUPPORTED ON ☐ STEEL ☐ CONCRETE ☐
③ VESSEL TOLERANCE – SEE STD. EF-1
④

TYPE OF PARTS AND MATERIAL SPECIFICATION

SHELL
HEAD

INTERNAL STEEL
EXTERNAL STEEL
INTERNAL PIPING
NOZZLE NECKS
NOZZLE FLANGES
MANHOLE – ☐ DAVIT ☐ HINGE
COUPLINGS
STUDS AND/OR BOLTS
NUTS
GASKETS

INSULATION SUPPORTS
INSULATION
PAINT

NOZZLE DATA

NOZZLE	SIZE	ASA	NOZZLE	FLANGE		DIM "A"	REMARKS
		RATING	SCH	TYPE	FACE	①	
A 1							
A 2							
A 3							
A 4							
A 5							
A 6							
A 7							
A 8							
A 9							
A 10							
A 11							
A 12							

PREPARED BY: DATE:

FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION
☐ AND AS NOTED HEREON

AUTHORIZATION NUMBER

REFERENCE NUMBER

SHEET OF

CHEMICAL CONSTRUCTION CORPORATION
VESSEL DATA SHEET "A"

CLIENT AND LOCATION

PLANT SECTION NAME AND SECTION NUMBER
CLAUS SECTION 500

FIRST & SECOND STAGE CLAUS REACTORS H501 A&B

DESIGN DATA	
	CODE
SP. GR. – PRODUCT	CODE STAMP ☐ YES ☐ NO
WORKING PRESS. 13 PSIG	STRESS RELIEVED NO
DESIGN PRESS 15 PSIG	RADIOGRAPHED ☐ SPOT ☐ FULLY
WORKING TEMP Varies °F	HAMMER TEST
DESIGN TEMP Shell 650° F	WIND PRESSURE
JOINT EFFICIENCY 70 %	**CORROSION ALLOWANCE**
HYDROSTATIC TEST	HEAD 1/8"
EARTHQUAKE FACTOR	
	SHELL 1/8"
ERECTION WEIGHT 89, 300 LB	INTERNAL PARTS
OPERATING WEIGHT 820,400 LB	

WEIGHT OF VESSEL FILLED WITH LB

CONSTRUCTION

INSPECTION BY

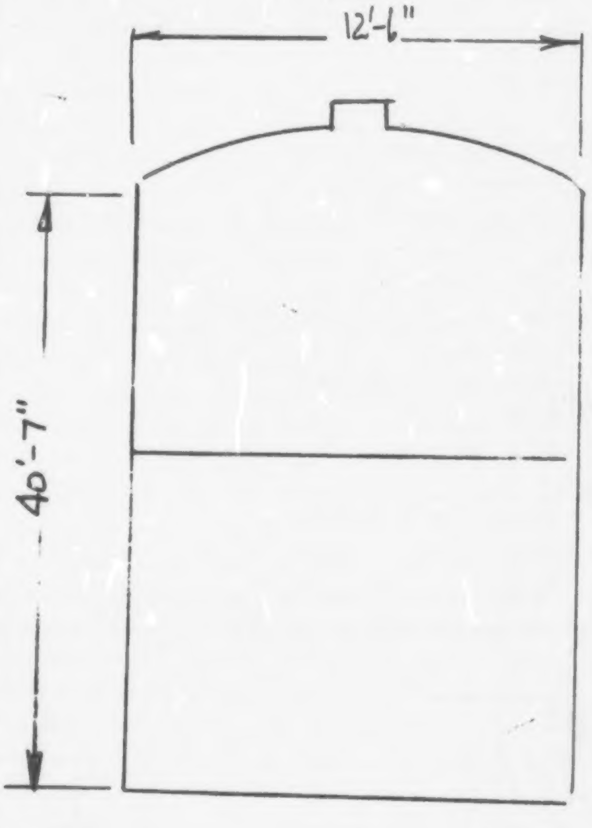
TYPE OF PARTS AND MATERIAL SPECIFICATION

SHELL
HEAD
INTERNAL STEEL
EXTERNAL STEEL
INTERNAL PIPING
NOZZLE NECKS
NOZZLE FLANGES
MANHOLE – ☐ DAVIT ☐ HINGE
COUPLINGS
STUDS AND/OR BOLTS
NUTS
GASKETS
INSULATION SUPPORTS
INSULATION
PAINT

NOZZLE DATA

NOZZLE	SIZE	ASA	NOZZLE	FLANGE		DIM "A"	REMARKS
		RATING	SCH	TYPE	FACE	①	
A 1							Gas In
A 2							Gas Out
A 3							Gas In
A 4							Gas Out
A 5							Manhole w cover
A 6							
A 7							
A 8							
A 9							
A 10							
A 11							
A 12							

① MEASURED FROM ℄ OF VESSEL TO FACE OF FLANGE
② VESSEL SUPPORTED ON ☐ STEEL ☐ CONCRETE ☐
③ VESSEL TOLERANCE – SEE STD. EF-1
④



ISSUE RECORD
DATE
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PREPARED BY:
DATE:
FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION ☐ AND AS NOTED HEREON
AUTHORIZATION NUMBER
REFERENCE NUMBER DD-H-501 A&B
SHEET 1 OF 2

CHEMICAL CONSTRUCTION CORPORATION

CENTRIFUGAL PUMP - PROPOSAL DATA SHEET

SHEET OF

ISSUE RECORD

DATE

APPROVED BY

ISSUE

DATE

APPROVED BY

ISSUE

AUTHORIZATION NO.

DATE:

PREPARED BY:

FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER SPECIFICATION AND AS NOTED HEREON

STD - SPA - 30

CLIENT AND LOCATION

PLANT SECTION NAME AND SECTION NUMBER

HOT WATER RECIRCULATION PUMP J-101 A&B

LIQUID CHARACTERISTICS

LIQUID PUMPED: DEIONIZED WATER
SPECIFIC GRAVITY AT FLOW TEMPERATURE:
FLOW TEMPERATURE: 140 °F
VISCOSITY AT FLOW TEMPERATURE (CENTIPOISE) (SSU):
VAPOR PRESSURE AT FLOW TEMPERATURE: 3 PSIA
PERCENT SOLIDS: SIZE SOLIDS

CAPACITIES AND PRESSURES

GPM (US) AT FLOW TEMPERATURE: NORMAL 140 DESIGN 200
DISCHARGE PRESSURE: 50 PSIG
SUCTION PRESSURE AT PUMP AT FLOW RATE: 20 PSIG
DIFFERENTIAL PRESSURE: 30 PSI
DIFFERENTIAL HEAD (FEET OF LIQUID PUMPED): 58 FEET
NPSH AVAILABLE (CENTER LINE OF IMPELLER): 100 FEET

DRIVER

INTEGRAL OR COUPLED SHAFT:
TYPE DRIVER: ☒ MOTOR ☐ TURBINE
DRIVER TO BE FURNISHED BY:
DRIVER TO BE MOUNTED BY:

CONSTRUCTION REQUIREMENTS

CASING TYPE: ☐ HORIZONTAL SPLIT ☐ VERTICAL SPLIT ☐ BARREL
CASING SUPPORT: ☐ FOOT ☐ VERTICAL ☐ CENTERLINE ☐ BRACKET
BASE PLATE REQUIRED: ☐ YES ☐ NO
EXTENDED FOR DRIVER: ☐ YES ☐ NO. DRAIN RIM REQUIRED: ☐ YES ☐ NO
COUPLING TYPE REQUIRED: GUARD REQUIRED: ☐ YES ☐ NO
STUFFING BOX PACKING REQUIRED: ☐ YES ☐ NO
STUFFING BOX JACKET REQUIRED: ☐ YES ☐ NO
MECHANICAL SEAL REQUIRED: ☐ YES ☐ NO TYPE:
BEARING COOLING REQUIRED: ☐ YES ☐ NO
BY-PASS COOLING ORIFICE PLATES REQUIRED: ☐ YES ☐ NO

MATERIAL CODE	INTERNAL CLASSIFICATION
I - CAST IRON	1 IRON
B - BRONZE	2 BRONZE
S - STEEL	3 STAINLESS STEEL (TYPE)
D - DUCTILE IRON	4 STEEL
C - CHROME STEEL (11-13% CHROME)	5 DUCTILE IRON
SS- STAINLESS STEEL (TYPE)	6 CHROME STEEL
A - ALLOY	
h - HARDENED f - FACED	

EXTERNAL CASING MATERIAL ☐

INTERNAL CLASSIFICATION ☐

INTERNAL CLASSIFICATION IDENTIFICATION	1	2	3	4	5	6	7
IMPELLER	I	B	SS	S	I	C	
INNER CASE PARTS	I	I & B	SS	S	I	C	
SHAFT SLEEVES (PACKED TYPE)	Ch	Ch	SS	Af	Af	Af	
SHAFT SLEEVES (MECH. SEAL TYPE)	C	C	SS	C	C	C	
WEAR RINGS (IF REQUIRE)	I	B	SS	Ch	Ch	Ch	
SHAFT	S	S	SS	S	S	S	

SHOP TESTS	REQUIRED	WITNESSED
RUNNING PERFORMANCE		
NPSH		

REMARKS:

CHEMICAL CONSTRUCTION CORPORATION

CENTRIFUGAL PUMP - PROPOSAL DATA SHEET

SHEET OF

ISSUE RECORD

DATE | APPROVED BY | ISSUE | DATE | APPROVED BY | ISSUE

AUTHORIZATION NO.

CLIENT AND LOCATION

PLANT SECTION NAME AND SECTION NUMBER

BOILER FEEDWATER PUMP J-102 A, B (Two Pumps Req'd)

LIQUID CHARACTERISTICS

LIQUID PUMPED: B.F. WATER

SPECIFIC GRAVITY AT FLOW TEMPERATURE: .943

FLOW TEMPERATURE: 250 °F

VISCOSITY AT FLOW TEMPERATURE (CENTIPOISE) (SSU):

VAPOR PRESSURE AT FLOW TEMPERATURE: 30 PSIA

PERCENT SOLIDS: SIZE SOLIDS

CAPACITIES AND PRESSURES

GPM (US) AT FLOW TEMPERATURE: NORMAL 135 DESIGN 170

DISCHARGE PRESSURE: 700 PSIG

SUCTION PRESSURE AT PUMP AT FLOW RATE: 15 PSIG

DIFFERENTIAL PRESSURE: 85 PSI

DIFFERENTIAL HEAD (FEET OF LIQUID PUMPED): FEET

NPSH AVAILABLE (CENTER LINE OF IMPELLER): FEET

DRIVER

INTEGRAL OR COUPLED SHAFT: Coupled

TYPE DRIVER: ☒ MOTOR or ☒ TURBINE

DRIVER TO BE FURNISHED BY:

DRIVER TO BE MOUNTED BY:

CONSTRUCTION REQUIREMENTS

CASING TYPE: ☐ HORIZONTAL SPLIT ☐ VERTICAL SPLIT ☐ BARREL

CASING SUPPORT: ☐ FOOT ☐ VERTICAL ☐ CENTERLINE ☐ BRACKET

BASE PLATE REQUIRED: ☐ YES ☐ NO

EXTENDED FOR DRIVER: ☐ YES ☐ NO. DRAIN RIM REQUIRED: ☐ YES ☐ NO

COUPLING TYPE REQUIRED: GUARD REQUIRED: ☐ YES ☐ NO

STUFFING BOX PACKING REQUIRED: ☐ YES ☐ NO

STUFFING BOX JACKET REQUIRED: ☐ YES ☐ NO

MECHANICAL SEAL REQUIRED: ☐ YES ☐ NO TYPE:

BEARING COOLING REQUIRED: ☐ YES ☐ NO

BY-PASS COOLING ORIFICE PLATES REQUIRED: ☐ YES ☐ NO

MATERIAL CODE

I - CAST IRON
B - BRONZE
S - STEEL
D - DUCTILE IRON
C - CHROME STEEL (11-13% CHROME)
SS- STAINLESS STEEL (TYPE)
A - ALLOY

h - HARDENED
f - FACED

INTERNAL CLASSIFICATION

1 IRON
2 BRONZE
3 STAINLESS STEEL (TYPE)
4 STEEL
5 DUCTILE IRON
6 CHROME STEEL

EXTERNAL CASING MATERIAL ☐

INTERNAL CLASSIFICATION ☐

INTERNAL CLASSIFICATION IDENTIFICATION	1	2	3	4	5	6	7
IMPELLER	I	B	SS	S	I	C	
INNER CASE PARTS	I	I & B	SS	S	I	C	
SHAFT SLEEVES (PACKED TYPE)	Ch	Ch	SS	Af	Af	Af	
SHAFT SLEEVES (MECH. SEAL TYPE)	C	C	SS	C	C	C	
WEAR RINGS (IF REQUIRE)	I	B	SS	Ch	Ch	Ch	
SHAFT	S	S	SS	S	S	S	

SHOP TESTS	REQUIRED	WITNESSED
RUNNING PERFORMANCE		
NPSH		

REMARKS:

DATE:

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FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER SPECIFICATION AND AS NOTED HEREON

☐ STD - SPA - 50

CHEMICAL CONSTRUCTION CORPORATION

CENTRIFUGAL PUMP - PROPOSAL DATA SHEET

SHEET OF

CLIENT AND LOCATION

PLANT SECTION NAME AND SECTION NUMBER

CONDENSATE PUMPS J-301A, B

1 **LIQUID CHARACTERISTICS**

LIQUID PUMPED: CONDENSATE

SPECIFIC GRAVITY AT FLOW TEMPERATURE:

FLOW TEMPERATURE: 120° °F

5 VISCOSITY AT FLOW TEMPERATURE (CENTIPOISE) (SSU):

VAPOR PRESSURE AT FLOW TEMPERATURE: PSIA

PERCENT SOLIDS: SIZE SOLIDS

CAPACITIES AND PRESSURES

10 GPM (US) AT FLOW TEMPERATURE: NORMAL 86 DESIGN 110

DISCHARGE PRESSURE: 45 PSIG

SUCTION PRESSURE AT PUMP AT FLOW RATE: 4" HgA PSIG

DIFFERENTIAL PRESSURE: PSI

DIFFERENTIAL HEAD (FEET OF LIQUID PUMPED): FEET

15 NPSH AVAILABLE (CENTER LINE OF IMPELLER): FEET

DRIVER

INTEGRAL OR COUPLED SHAFT: VERTICAL INLINE

TYPE DRIVER: ☒ MOTOR ☐ TURBINE

20 DRIVER TO BE FURNISHED BY:

DRIVER TO BE MOUNTED BY: PUMP MF a/c

CONSTRUCTION REQUIREMENTS

CASING TYPE: ☐ HORIZONTAL SPLIT ☐ VERTICAL SPLIT ☐ BARREL

25 CASING SUPPORT: ☐ FOOT ☐ VERTICAL ☐ CENTERLINE ☐ BRACKET

BASE PLATE REQUIRED: ☐ YES ☐ NO

EXTENDED FOR DRIVER: ☐ YES ☐ NO. DRAIN RIM REQUIRED: ☐ YES ☐ NO

COUPLING TYPE REQUIRED: GUARD REQUIRED: ☐ YES ☐ NO

STUFFING BOX PACKING REQUIRED: ☐ YES ☐ NO

30 STUFFING BOX JACKET REQUIRED: ☐ YES ☐ NO

MECHANICAL SEAL REQUIRED: ☐ YES ☐ NO TYPE:

BEARING COOLING REQUIRED: ☐ YES ☐ NO

BY-PASS COOLING ORIFICE PLATES REQUIRED: ☐ YES ☐ NO

35

MATERIAL CODE	INTERNAL CLASSIFICATION
I - CAST IRON	1 IRON
B - BRONZE	2 BRONZE
S - STEEL	3 STAINLESS STEEL (TYPE)
D - DUCTILE IRON	4 STEEL
C - CHROME STEEL (11-13% CHROME)	5 DUCTILE IRON
SS- STAINLESS STEEL (TYPE)	6 CHROME STEEL
A - ALLOY	

h - HARDENED
f - FACED

EXTERNAL CASING MATERIAL ☐

INTERNAL CLASSIFICATION ☐

INTERNAL CLASSIFICATION IDENTIFICATION	1	2	3	4	5	6	7
IMPELLER	I	B	SS	S	I	C	
INNER CASE PARTS	I	I & B	SS	S	I	C	
SHAFT SLEEVES (PACKED TYPE)	Ch	Ch	SS	Af	Af	Af	
SHAFT SLEEVES (MECH. SEAL TYPE)	C	C	SS	C	C	C	
WEAR RINGS (IF REQUIRE)	I	B	SS	Ch	Ch	Ch	
SHAFT	S	S	SS	S	S	S	

40 45 50

SHOP TESTS	REQUIRED	WITNESSED
RUNNING PERFORMANCE		
NPSH		

55 REMARKS:

ISSUE RECORD

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CHEMICAL CONSTRUCTION CORPORATION

CENTRIFUGAL PUMP – PROPOSAL DATA SHEET

SHEET OF

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CLIENT AND LOCATION

PLANT SECTION NAME AND SECTION NUMBER

SULFUR PUMPS J501 A&B (Two Pumps Req'd)

LIQUID CHARACTERISTICS

LIQUID PUMPED: LIQUID SULFUR

SPECIFIC GRAVITY AT FLOW TEMPERATURE: 1.78

FLOW TEMPERATURE: 300° F °F

VISCOSITY AT FLOW TEMPERATURE (CENTIPOISE) (SSU): 70

VAPOR PRESSURE AT FLOW TEMPERATURE: 3 PSIA

PERCENT SOLIDS: SIZE SOLIDS

CAPACITIES AND PRESSURES

GPM (US) AT FLOW TEMPERATURE: NORMAL 10.9 DESIGN 15

DISCHARGE PRESSURE: 20 PSIG

SUCTION PRESSURE AT PUMP AT FLOW RATE: 3 PSIG

DIFFERENTIAL PRESSURE: 17 PSI

DIFFERENTIAL HEAD (FEET OF LIQUID PUMPED): 22 FEET

NPSH AVAILABLE (CENTER LINE OF IMPELLER): 15 FEET

DRIVER

INTEGRAL OR COUPLED SHAFT: COUPLED

TYPE DRIVER: ☒ MOTOR ☐ TURBINE

DRIVER TO BE FURNISHED BY:

DRIVER TO BE MOUNTED BY: PUMP MF Gr

CONSTRUCTION REQUIREMENTS

CASING TYPE: ☐ HORIZONTAL SPLIT ☐ VERTICAL SPLIT ☐ BARREL

CASING SUPPORT: ☐ FOOT ☐ VERTICAL ☐ CENTERLINE ☐ BRACKET

BASE PLATE REQUIRED: ☐ YES ☐ NO

EXTENDED FOR DRIVER: ☐ YES ☐ NO. DRAIN RIM REQUIRED: ☐ YES ☐ NO

COUPLING TYPE REQUIRED: GUARD REQUIRED: ☐ YES ☐ NO

STUFFING BOX PACKING REQUIRED: ☐ YES ☐ NO

STUFFING BOX JACKET REQUIRED: ☐ YES ☐ NO

MECHANICAL SEAL REQUIRED: ☐ YES ☐ NO TYPE:

BEARING COOLING REQUIRED: ☐ YES ☐ NO

BY-PASS COOLING ORIFICE PLATES REQUIRED: ☐ YES ☐ NO

MATERIAL CODE	INTERNAL CLASSIFICATION
I – CAST IRON	1 IRON
B – BRONZE	2 BRONZE
S – STEEL	3 STAINLESS STEEL (TYPE)
D – DUCTILE IRON	4 STEEL
C – CHROME STEEL (11-13% CHROME)	5 DUCTILE IRON
SS- STAINLESS STEEL (TYPE)	6 CHROME STEEL
A – ALLOY	
[h – HARDENED f – FACED]	

EXTERNAL CASING MATERIAL ☐

INTERNAL CLASSIFICATION ☐

INTERNAL CLASSIFICATION IDENTIFICATION	1	2	3	4	5	6	7
IMPELLER	I	B	SS	S	I	C	
INNER CASE PARTS	I	I & B	SS	S	I	C	
SHAFT SLEEVES (PACKED TYPE)	Ch	Ch	SS	Af	Af	Af	
SHAFT SLEEVES (MECH. SEAL TYPE)	C	C	SS	C	C	C	
WEAR RINGS (IF REQUIRE)	I	B	SS	Ch	Ch	Ch	
SHAFT	S	S	SS	S	S	S	

SHOP TESTS	REQUIRED	WITNESSED
RUNNING PERFORMANCE		
NPSH		

REMARKS:

09 – 4926

CHEMICAL CONSTRUCTION (G.B.) LTD.

DATA SHEET
CENTRIFUGAL COMPRESSOR OR BLOWER

PAGE 1 OF 1

CLIENT	AND	LOCATION	AUTHORIZATION NO.
NAME OF UNIT START-UP VENT BLOWER	AND	UNITS REQ'D	CODE NO. K101
PLANT SECTION NAME CALCINER SECTION	AND		SECTION NO.

OPERATING CONDITIONS

				GAS ANALYSIS	MOL. %	PPH
1	MATERIAL HANDLED	Feed Gas				
2	CORROSION DUE TO	SO_2-H_2O		SO_2	13.1	
3	RELATIVE HUMIDITY	29.7%	"N" VALUE	H_2O	14.8	
4	MOL. WEIGHT AT INTAKE COND.-MAX.		MIN.	CO_2	8.8	
5	INTAKE TEMPERATURE	300	°F	N_2	63.0	
6	INTAKE PRESSURE	14.2	PSIA	O_2	.3	
7	DISCHARGE PRESSURE	14.7	PSIA		100.0	
8	BAROMETRIC PRESSURE	14.7	PSIA			
9	DISCHARGE TEMPERATURE		°F			
10	NORMAL CAPACITY AT INTAKE COND.	92,075	PPH			
11	14.7 PSI @ 60°F	26,020	CFM			
12	DESIGN CAPACITY AT INTAKE COND.	95,200	PPH			
13		28,000	CFM			
14	BHP AT COUPLING — NORMAL	DESIGN				
15	DRIVER HP					
16	RPM—NORMAL	PUMP POINT	CFM			
17	RPM—DESIGN	PUMP POINT	CFM			
18						

TYPE OF PARTS AND MATERIAL SPECIFICATIONS
EQUIPMENT TO BE FURNISHED IN ACCORDANCE WITH CHEMICO SPECIFICATION

19	MANUFACTURER		CASE MATERIAL		
20	TYPE		NO. STAGES		
21	DRIVER-TYPE Electric Motor		HP	SPEED	RPM
22	SHAFT—		CRITICAL SPEED		RPM
23	ROTOR—				
24	ROTATION—				
25	AUXILIARY OIL PUMP—				
26	FILTERS				
27	INTAKE FLANGE	SIZE	RATING	FACING	
28	DISCHARGE FLANGE	SIZE	RATING	FACING	
29	SEALS				
30	BEARINGS—INTERNAL				
31	BEARINGS—EXTERNAL				
32	THRUST BEARINGS—				
33	LABYRINTHS—				
34	TEST—PERFORMANCE				
35	CONTROLS				
36					
37					
38					

		SHELL SIDE-OIL		TUBE SIDE-WATER	
39	LUBE OIL COOLERS— NO. REQUIRED				
40	QUANTITY OF FLUID CIRCULATED		GPM		GPM
41	TEMPERATURE, OF	IN	OUT	IN	OUT
42	MAX. ALLOWABLE WORKING PRESSURE		PSIG		PSIG
43	PRESSURE DROP		PSIG		PSIG
44	NET WEIGHT, ( ) AND BASE				
45	HEAVIEST WEIGHT TO BE LIFTED—DURING ERECTION		DURING MAINTENANCE		

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OAGR - 4574

CHEMICAL CONSTRUCTION CORPORATION
DATA SHEET
CENTRIFUGAL COMPRESSOR

PAGE OF

CLIENT	AND	LOCATION	AUTHORIZATION NO.
NAME OF UNIT FEED COMPRESSOR	AND	UNITS REQ'D ONE	CODE NO. K-206
PLANT SECTION NAME	AND		SECTION NO.

OPERATING CONDITIONS

1	MATERIAL HANDLED	Feed			GAS ANALYSIS	MOL. %	PPH
2	CORROSION DUE TO	SO_2			SO_2	13.09	
3	RELATIVE HUMIDITY	"N" VALUE			H_2O	14.82	
4	MOL. WEIGHT AT INTAKE COND.-MAX.	MIN.			CO_2	8.79	
5	INTAKE TEMPERATURE		170	°F	N_2	63.04	
6	INTAKE PRESSURE		12.0	PSIA	O_2	.26	
7	DISCHARGE PRESSURE		40	PSIA			
8	BAROMETRIC PRESSURE		14.7	PSIA			
9	DISCHARGE TEMPERATURE			°F			
10	NORMAL CAPACITY AT INTAKE COND.		90,981	PPH			
11	14.7 PSI @ 60°F		17,800	CFM			
12	DESIGN CAPACITY AT INTAKE COND.		95,180	PPH			
13				CFM			
14	BHP AT COUPLING - NORMAL	DESIGN					
15	DRIVER HP						
16	RPM-NORMAL	PUMP POINT		CFM			
17	RPM-DESIGN	PUMP POINT		CFM			
18							

TYPE OF PARTS AND MATERIAL SPECIFICATIONS
EQUIPMENT TO BE FURNISHED IN ACCORDANCE WITH CHEMICO SPECIFICATION

19	MANUFACTURER		CASE MATERIAL	
20	TYPE		NO. STAGES	
21	DRIVER-TYPE	Condensing - St. Turbine	HP	SPEED RPM
22	SHAFT -		CRITICAL SPEED	RPM
23	ROTOR -			
24	ROTATION -			
25	AUXILIARY OIL PUMP -			
26	FILTERS			
27	INTAKE FLANGE	SIZE	RATING	FACING
28	DISCHARGE FLANGE	SIZE	RATING	FACING
29	SEALS			
30	BEARINGS - INTERNAL			
31	BEARINGS - EXTERNAL			
32	THRUST BEARINGS -			
33	LABYRINTHS -			
34	TEST - PERFORMANCE			
35	CONTROLS			
36				
37				
38				

39	LUBE OIL COOLERS - NO. REQUIRED	SHELL SIDE-OIL	TUBE SIDE-WATER
40	QUANTITY OF FLUID CIRCULATED	GPM	GPM
41	TEMPERATURE, OF	IN OUT	IN OUT
42	MAX. ALLOWABLE WORKING PRESSURE	PSIG	PSIG
43	PRESSURE DROP	PSIG	PSIG
44	NET WEIGHT, ( ) AND BASE		
45	HEAVIEST WEIGHT TO BE LIFTED - DURING ERECTION	DURING MAINTENANCE	

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CCC - 4674 10/57

CHEMICAL CONSTRUCTION CORPORATION

INDUSTRIAL & HEAVY DUTY FANS

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CLIENT AND LOCATION

PLANT SECTION NAME AND SECTION NUMBER

ITEM NO.
K-601

SERVICE Incinerator Air

OPERATING CONDITIONS

Number of Units Required One Air
Barometric Pressure, PSIA 14.7

Gas Composition		Design Rating	Normal Operation
Air	Capacity, Lbs/Hr		24,006
N_2 79%	Inlet Pressure, PSIA	Atmospheric	<14.7
	Inlet Temp., ° F		60°
	Inlet CFM		5,190
	Statis Press. Rise, In. W.G.		75" H_2O
	BHP at Fan Shaft		
	Fan Speed, RPM		

Startup Temperature, ° F 60
Fan BHP at Startup
Max. Allowable Temp., ° F

Max. Continuous Speed, RPM
Max. Tip Speed, FPM
Max. Outlet Velocity, FPM

CONSTRUCTION
Fan Type
☐ SWSI ☐ DWDI ☐ Split Housing

DRIVER ☒ By Mfr.
Type Motor Drive
Rated BHP Service Factor

PREPARED BY: DATE:
FURNISH IN ACCORDANCE VITH BUYER'S PURCHASE ORDER AND SPECIFICATION
☐ AND AS NOTED HEREON
AUTHORIZATION NUMBER
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SHEET OF

04-4551 REV. 1

CHEMICAL CONSTRUCTION CORPORATION
DATA SHEET
CENTRIFUGAL COMPRESSOR OR BLOWER

PAGE OF

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ISSUE

CLIENT	AND	LOCATION	AUTHORIZATION N
NAME OF UNIT AIR COMPRESSOR	AND	UNITS REQ'D ONE	CODE NO. K-207
PLANT SECTION NAME	AND		SECTION NO.

OPERATING CONDITIONS

1	MATERIAL HANDLED	Air			GAS ANALYSIS	MOL.%	PPH
2	CORROSION DUE TO				N_2	75	
3	RELATIVE HUMIDITY	100%	"N" VALUE		O_2	20	
4	MOL. WEIGHT AT INTAKE COND.–MAX.	29	MIN.		H_2O	5	
5	INTAKE TEMPERATURE		90	°F			
6	INTAKE PRESSURE		Atm.	PSIA			
7	DISCHARGE PRESSURE		94.7	PSIA			
8	BAROMETRIC PRESSURE		14.7	PSIA			
9	DISCHARGE TEMPERATURE		100	°F			
10	NORMAL CAPACITY AT INTAKE COND.		23,382	PPH			
11	14.7 PSI @ 60°F		5,076	CFM			
12	DESIGN CAPACITY AT INTAKE COND.		25,382	PPH			
13				CFM			
14	BHP AT COUPLING – NORMAL		DESIGN				
15	DRIVER HP						
16	RPM–NORMAL	PUMP POINT		CFM			
17	RPM–DESIGN	PUMP POINT		CFM			
18							

TYPE OF PARTS AND MATERIAL SPECIFICATIONS
EQUIPMENT TO BE FURNISHED IN ACCORDANCE WITH CHEMICO SPECIFICATION

19	MANUFACTURER		CASE MATERIAL		
20	TYPE		NO. STAGES		
21	DRIVER–TYPE Condensing - St. Turbine		HP	SPEED	RP
22	SHAFT –		CRITICAL SPEED		RPM
23	ROTOR –				
24	ROTATION –				
25	AUXILIARY OIL PUMP –				
26	FILTERS				
27	INTAKE FLANGE	SIZE	RATING	FACING	
28	DISCHARGE FLANGE	SIZE	RATING	FACING	
29	SEALS				
30	BEARINGS – INTERNAL				
31	BEARINGS – EXTERNAL				
32	THRUST BEARINGS –				
33	LABYRINTHS –				
34	TEST – PERFORMANCE				
35	CONTROLS				
36					
37					
38					

39	LUBE OIL COOLERS – NO. REQUIRED	SHELL SIDE–OIL		TUBE SIDE–WATER	
40	QUANTITY OF FLUID CIRCULATED		GPM		GPM
41	TEMPERATURE, OF	IN	OUT	IN	OU
42	MAX. ALLOWABLE WORKING PRESSURE		PSIG		PSIG
43	PRESSURE DROP		PSIG		PSIG
44	NET WEIGHT,( )AND BASE				
45	HEAVIEST WEIGHT TO BE LIFTED–DURING ERECTION		DURING MAINTENANCE		

PREPARED BY	DATE	DRAWING NO.

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CHEMICAL CONSTRUCTION CORPORATION

CLIENT AND LOCATION

PLANT SECTION NAME AND SECTION NUMBER

E-501

ISSUE RECORD

DATE | APPROVED BY | ISSUE | DATE | APPROVED BY | ISSUE | DATE | APPROVED BY | ISSUE | DATE | APPROVED BY | ISSUE

CLAUS SECTION WASTE HEAT BOILER

Furnish ONE (1) CLAUS SECTION Waste Heat Boiler(s) in accordance with attached standard specification for WASTE HEAT BOILER FIRETUBE TYPE and this requisition and all attachments. Where conflicts exist between the standard specification and this requisition, the requisition shall govern. The boiler(s) will be installed and shall meet all local ordinances and regulations in addition to the code requirements called for in the standard specification.

DESIGN CONDITIONS: (For Each Unit)

1.	Rating	100%
2.	Steam Capacity	6219 LB/HR
3.	Operating Press at Boiler Outlet	80 PSIG
4.	Steam Temp. at Boiler Outlet	Sat. °F
5.	Feedwater Temperature	250 °F
6.	Continuous Blowdown	190 LB/HR %
7.	Efficiency of Unit	97 %
8.	Design Pressure (Water Side)	160 PSIG
9.	Elevation	Sea Level
10.	Waste Heat	Claus Reactor
a.	Flow: Dry Gay	LB/HR
	H_2O	LB/HR
	Total	125, 484 LB/HR
b.	Wet Gas Composition	H_2S=3. 6 % Vol. SO_2=1. 8 H_2O=27. 2 CO_2=11. 9 N_2=54. 3 H_2 0. 7; CH_4=0. 03 Sulfur Vapor 0. 5%
c.	Inlet Temperature	750° F
d.	Inlet Pressure	10 PSIG
e.	Maximum Pressure Drop	0. 7 PSI
f.	Gas Side Design Pressure	20 PSIG
g.	Gas Outlet Temperature	6. 20 580 °F
h.	Heat Exchanged (given up by gas)	x 10^{+6} BTU/HR

i. Fouling Factor: Water Side __________ Gas Side __________

J. Corrosion Allowance: Water Side _____ Gas Side __________

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FURNISH IN ACCORDANCE WITH BUYER'S PURCHASE ORDER AND SPECIFICATION AND AS NOTED HEREON ☐

SHEET OF

XVI
CASE D SYSTEM

1. PROCESS DESCRIPTION

1.1 Fuel Milling and Combustion

An HSC Fuel of the CASE C and D composition (See Table XI-1) containing 21.1% iron pyrite is milled to p.c. size and conveyed by preheated air to the horizontal burners of the 500 MW Furnace, through the combustion and absorption zones and the preheaters, to the Cyclone Collector at the boiler exit. Combustion and steam generation proceed as described in PART XI. The steam is of subcritical quality for turbo-generator drive as shown in the flow diagram CASE D, Sheet 1, together with the distribution of ash, the flue gas composition, and other data.

1.2 Flue Gas Cleaning (See Chemico process Sheet 1 following page XVI-4)

Combustion gas at 500° F containing about 1% SO_2 flows from the cyclone collector at the boiler exit to a Venturi-Scrubber wherein the remaining fly ash and acid mist are removed by entrainment in weak sulfuric acid solution in which SO_2 is only slightly soluble. This scrubbing solution is purged continually to the solids disposal circuit that includes provision for lime-neutralization of the entrained sulfur oxides so that these compounds will precipitate and be collected together with the fly ash in the Thickener and waste solids Centrifuge.

1.3 Recovery of SO_2 as Magnesium Sulfur Salts.

1.3.1 Absorption

The cool, cleaned flue gas, still of about 1% SO_2 concentration, is brought into intimate contact with the absorbing liquid slurry containing $MgSO_3$, $MgSO_4$ and MgO in a two-stage Venturi-type mass transfer device. The gas and liquid flow co-currently, i.e., both phases move through the absorption equipment in the same direction. The flue gas is accelerated as the gas approaches the throat section of the Venturi. This higher level of gas energy is transferred to the liquid, possessing lower energy, causing it to break up into droplets. On the surface of these droplets, the SO_2 from the gas phase diffuses into and chemically reacts with the solid and solute phases of $MgSO_3$ and MgO.

The SO_2 is absorbed in accordance with the following chemical reactions:

$$MgO + SO_2 \longrightarrow MgSO_3$$

$$MgSO_3 + SO_2 + H_2O \longrightarrow Mg(HSO_3)_2$$

$$Mg\,(HSO_3)_2 + MgO \longrightarrow 2\ MgSO_3 + H_2O$$

$$MgO + SO_3 \longrightarrow MgSO_4$$

$$MgSO_3 + 1/2O_2 \longrightarrow MgSO_4$$

The recirculating liquor contains $MgSO_3$, $MgSO_4$ and MgO. The make-up to the absorption system is a suitable MgO slurry.

Downstream of this absorption reaction the SO_2 is freed in a gas concentrate for conversion to some marketable form of sulfur value such as sulfuric acid, sulfur dioxide, or in CASE D, sulfur. Since none of these conversions can be carried to completion it is convenient in each instance to return the loss of product yield to this absorption step in the form of SO_2. In CASE D, Sheet 1, it is shown that uncaptured sulfur value is returned from the sulfur plant to the absorption step for recycling in this manner.

The flue gas and liquor leaving the Venturi enter the Cyclonic Separator, where any entrained liquor is separated. The flue gas is exhausted to the atmosphere through the Stack.

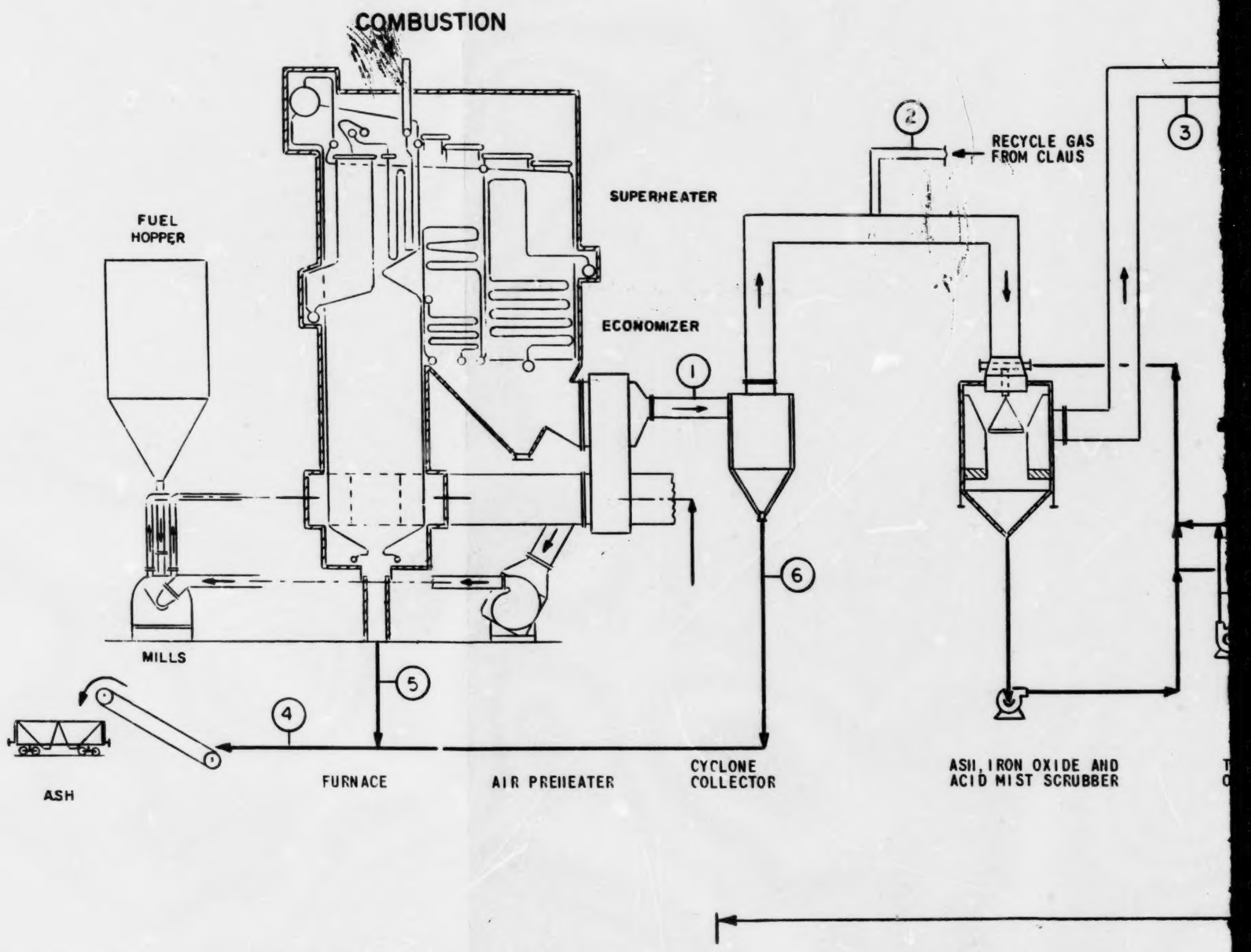
1.3.2 Centrifuging

A continuous bleed of 10-15% slurry is maintained from the absorption system to the product Centrifuge, where a centrifuged cake containing approximately 5% surface moisture is obtained. The mother liquor is returned to the absorption system through a holding tank.

1.3.3 Drying

The centrifuged cake, consisting of $MgSO_3 \cdot 6H_2O$, $MgSO_4 \cdot 7H_2O$, MgO and surface moisture is fed to the direct-fired Dryer by gravity flow, where combined and surface water are removed. The flue gas leaving the dryer is discharged to the atmosphere through a Dry Cyclone.

The dryer product, consisting of $MgSO_3$, $MgSO_4$ and MgO, is free flowing and stable, and may be processed on site or shipped. If the dryer product is shipped, return shipment of MgO, or other disposition of it, will be necessary.


COMBUSTION
FUEL HOPPER
SUPERHEATER
ECONOMIZER
RECYCLE GAS FROM CLAUS
2
3
1
6
5
4
MILLS
ASH
FURNACE
AIR PREHEATER
CYCLONE COLLECTOR
ASH, IRON OXIDE AND ACID MIST SCRUBBER
T
C

HSC COMBUSTOR

FUEL:

TOTAL FUEL FLOW	570,000 LBS/HR
IRON PYRITE	119,000
COAL COMBUSTIBLES	337,000
NON-PYRITIC ASH	114,000
HIGHER HEATING VALUE	9,000 BTU/LB
ENERGY INPUT	$5,130 \times 10^6$ BTU/HR

ASH DISTRIBUTION:

DRY ASH	165,000 LBS/HR
WET ASH	30.900
LIME SOLIDS	17,300
TOTAL WASTE SOLIDS	213,200 LBS/HR
% IRON IN DRY ASH	29

STEAM SECTION:

STEAM FLOW	3,500,000 LBS/HR
STEAM PRESSURE	2500 PSIG
STEAM TEMPERATURE	1005°F
NET HEAT OUTPUT	4.220×10^6 BTU/HR
REHEAT: PRESSURE IN	580 PSIG
TEMPERATURE IN	629°F
PRESSURE OUT	555°PSIG
TEMPERATURE OUT	1005°F
FEEDWATER	480°F
FLUE GAS EXIT	500°F

ELECTRICAL SECTION:

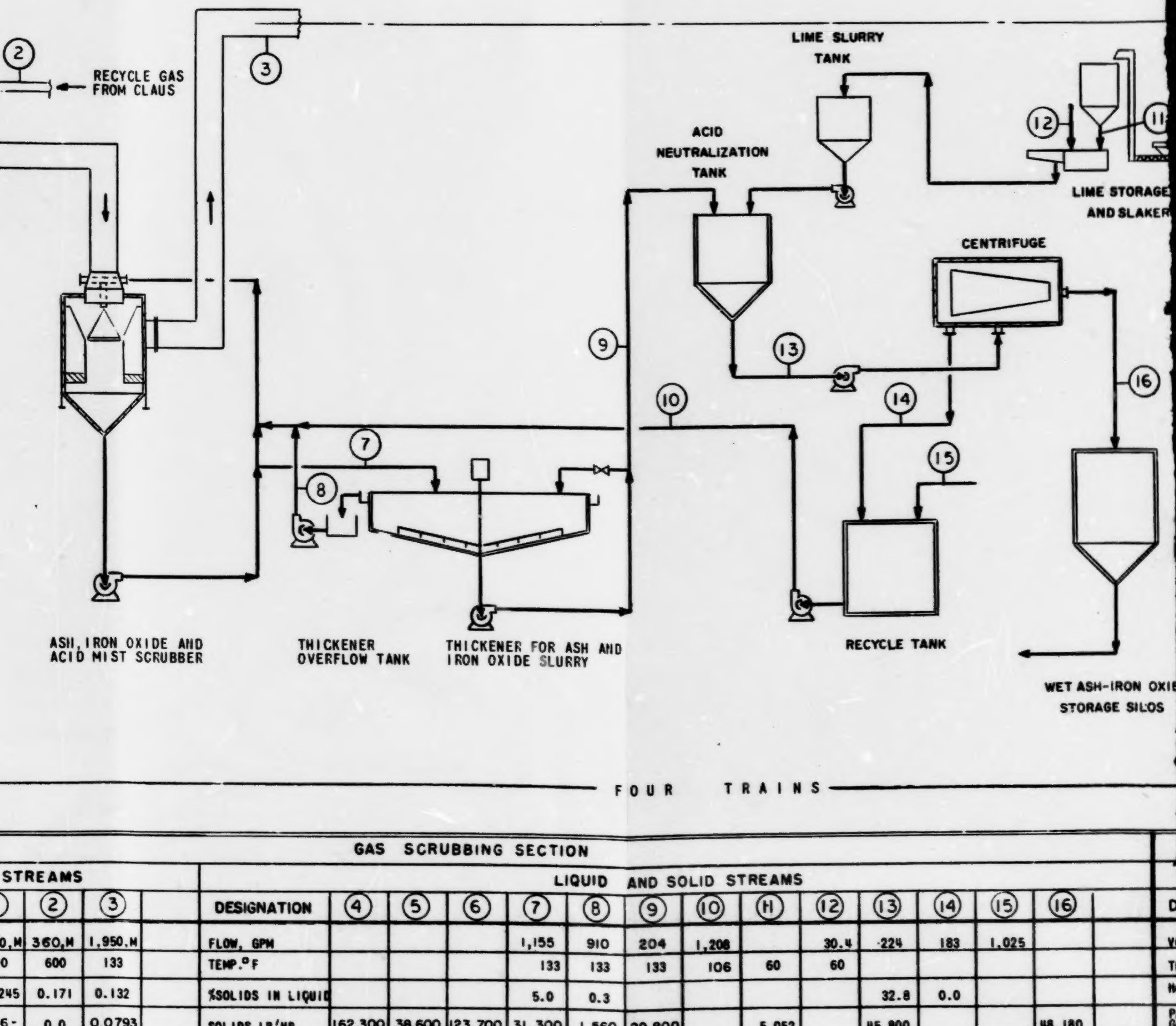
GENERATOR OUTPUT	500 MWH/HR
GROSS HEAT RATE	10.250 BTU/KWH
LOADING	8.000 HRS/YEAR

GAS STREAMS

DESIGNATION	①	②	③	
VOLUME, ACFM	2,140,M	360,M	1,950,M	
TEMP.°F	500	600	133	
HUMIDITY LB/LB	0.0245	0.171	0.132	
PARTICULATE GR/SCF	15.6-	0.0	0.0793	
SO_2 ppm	10,940	13,000	9.790	
H_2SO_4 mg/SCF			3.0	
SO_3 ppm	437	498		
PRES:-IN H_2O	0.0	0.0	42.	

DESIGNATIO
FLOW, GPM
TEMP.°F
%SOLIDS IN LI
SOLIDS, LB/HR
%H_2SO_4 IN LIQU
%H_2O IN SOLIDS
%Fe_2O_3 IN SOLI

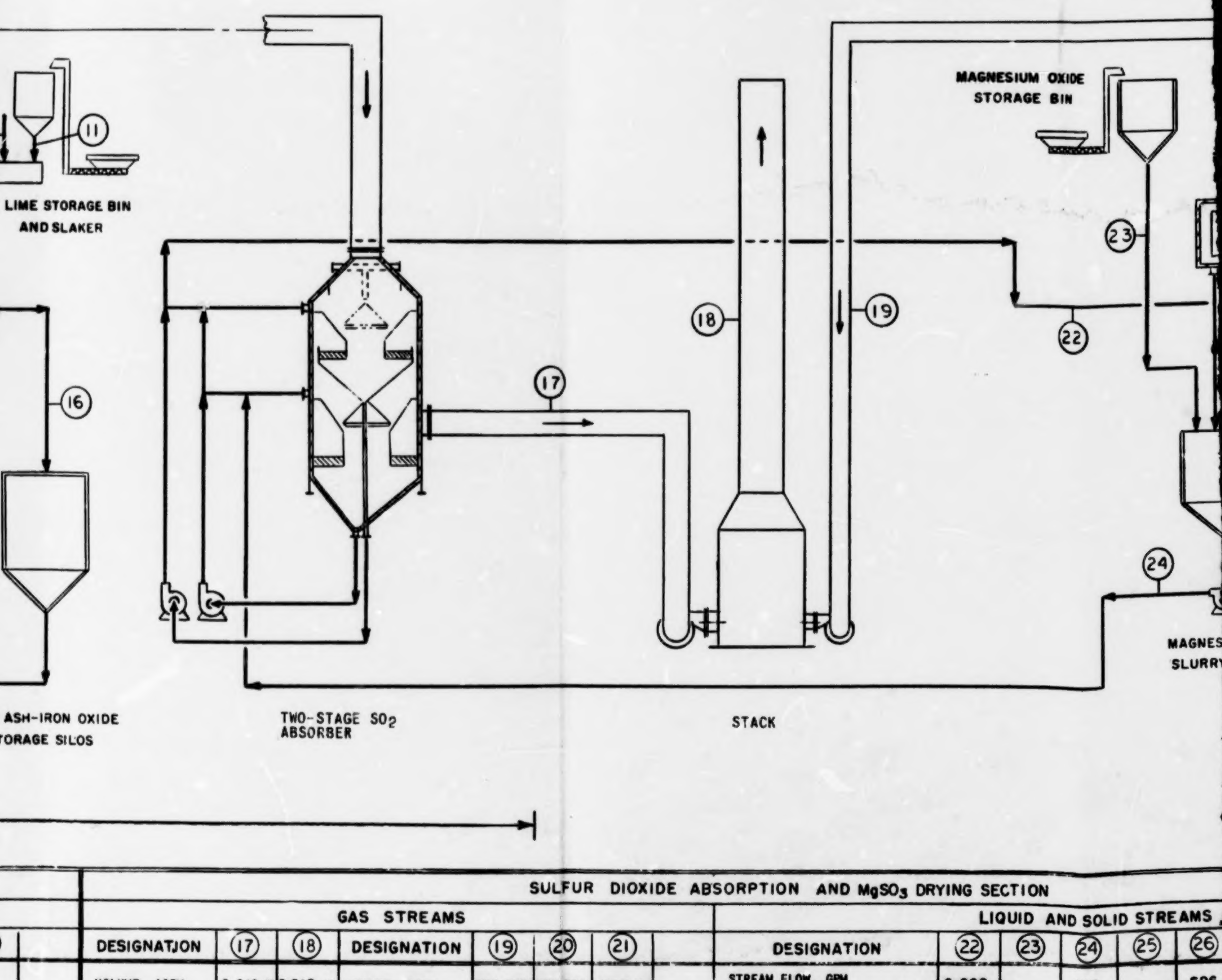
GAS SCRUBBING


②
RECYCLE GAS FROM CLAUS
③
LIME SLURRY TANK
ACID NEUTRALIZATION TANK
⑫
⑪
LIME STORAGE AND SLAKER
CENTRIFUGE
⑨
⑬
⑯
⑩
⑭
⑦
⑮
⑧
ASH, IRON OXIDE AND ACID MIST SCRUBBER
THICKENER OVERFLOW TANK
THICKENER FOR ASH AND IRON OXIDE SLURRY
RECYCLE TANK
WET ASH-IRON OXI
STORAGE SILOS
FOUR TRAINS

GAS SCRUBBING SECTION

STREAMS				LIQUID AND SOLID STREAMS															
)	②	③		DESIGNATION	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭	⑮	⑯		D
0,M	360,M	1,950,M		FLOW, GPM				1,155	910	204	1,208		30.4	·224	183	1,025			VO
0	600	133		TEMP.°F				133	133	133	106	60	60						TE
245	0.171	0.132		%SOLIDS IN LIQUID				5.0	0.3					32.8	0.0				HU
6-	0.0	0.0793		SOLIDS, LB/HR	162,300	38,600	123,700	31,300	1,560	29,800		5,052		45,800			48,180		PA GR
40	13,000	9.790		%H_2SO_4 IN LIQUID				9.6	9.6	9.6				0.0					SO
		3.0		%H_2O IN SOLIDS													5.0		H
7	498			%Fe_2O_3 IN SOLIDS	40.9	40.9	40.9												SO
0	0.0	42.																	PR

SO$_2$ ABSORPTION AND MAGNISIUM SULFATE


MAGNESIUM OXIDE
STORAGE BIN
11
LIME STORAGE BIN
AND SLAKER
16
17
18
19
22
23
24
ASH-IRON OXIDE
TORAGE SILOS
TWO-STAGE SO2
ABSORBER
STACK
MAGNES
SLURRY

SULFUR DIOXIDE ABSORPTION AND MgSO$_3$ DRYING SECTION

GAS STREAMS

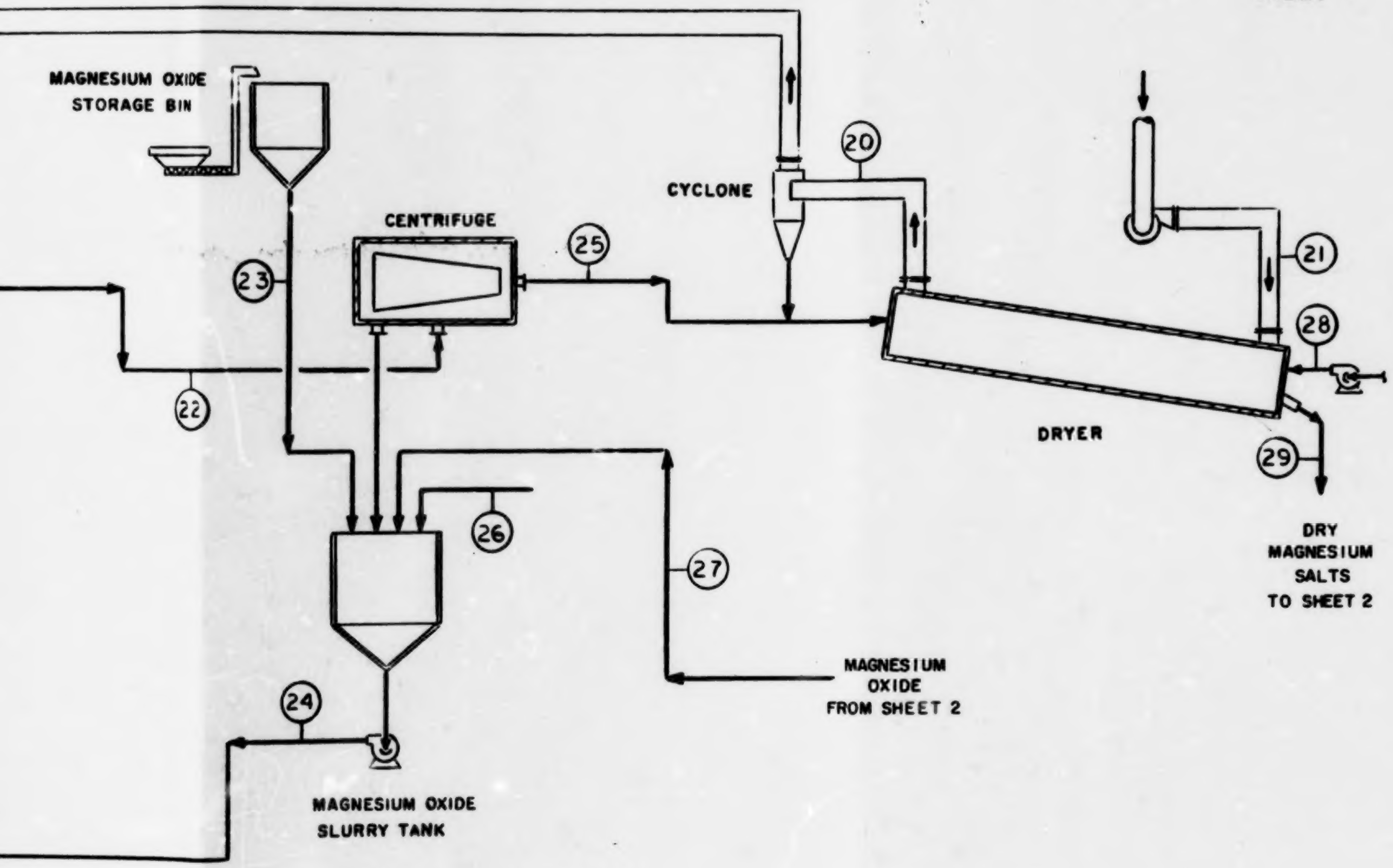
DESIGNATJON	⑰	⑱	DESIGNATION	⑲	⑳	㉑	
VOLUME, ACFM	2,010. M	2,510 . M	VOLUME, ACFM	806,700	806,700	380. M	
TEMP.° F	135	195	TEMP.° F	400	400	60	
HUMIDITY LB/LB	0.151	0.166	HUMIDITY LB/LB	0.20	0.20	0.003	
PARTICULATE GR/SCF	0.0793	0.13	PARTICULATE GR/SCF	0.31	3.1	0.0	
SO$_2$ ppm	105	79	%SO$_2$	NIL	NIL	0.0	
H$_2$SO$_4$ mg/SCF	3.0	2.25					
SO$_3$ ppm	NIL	NIL					
PRESS:-IN H$_2$O	58						

LIQUID AND SOLID STREAMS

DESIGNATION	㉒	㉓	㉔	㉕	㉖
STREAM FLOW, GPM	6,860		713		696
SOLIDS FLOW, LBS/HR	522. M	1,165	116.5M	549,. M	
TEMPERATURE°F	135	60			60
%SOLIDS IN LIQUID STREAM	13.		3.0		
HYDRATED MAGNESIUM SULFUR SALTS, LBS/HR	497. M			497. M	
ANHYDROUS MAGNESIUM SULFUR SALTS, LBS/HR	243, M			243, M	
MgO, LBS/HR	25,150	1,180*	118,000	25,150	
FUEL OIL, GPM					
		*1% OVERALL LOSS			

AND MAGNISIUM SULFATE RECOVERY

CASE D
SHEET I


MAGNESIUM OXIDE STORAGE BIN
CENTRIFUGE
CYCLONE
⑳
㉑
㉒
㉓
㉔
㉕
㉖
㉗
㉘
㉙
DRYER
DRY MAGNESIUM SALTS TO SHEET 2
MAGNESIUM OXIDE FROM SHEET 2
MAGNESIUM OXIDE SLURRY TANK

THREE TRAINS

DRYING SECTION								
LIQUID AND SOLID STREAMS								
㉒	㉓	㉔	㉕	㉖	㉗	㉘	㉙	
6,860		713		696				
522. M	1,165	116.5M	549,. M				267,000	
135	60			60				
13.		3.0						
497. M			497. M					
243, M			243, M				241,800	
25,150	1,180*	118,000	25,150		117,500		25,150	
					84.7			
	*1% OVERALL LOSS							

HIGH SULFUR COMBUSTOR STUDY

FLOW SHEET AND QUANTITIES

o

ENERGY PRODUCT

ELECTRICITY 500 MEGAWATTS CAPACITY

4,000,000 MWH/YEAR

INTERMEDIATE CHEMICAL PRODUCT

DRY MAGNESIUM SALTS

EQUIVALENT TO 770 TONS/DAY OF SULFUR

1.4 Calcining of Magnesium Sulfur Salts. (See flow diagram CASE D, Sheet 2)

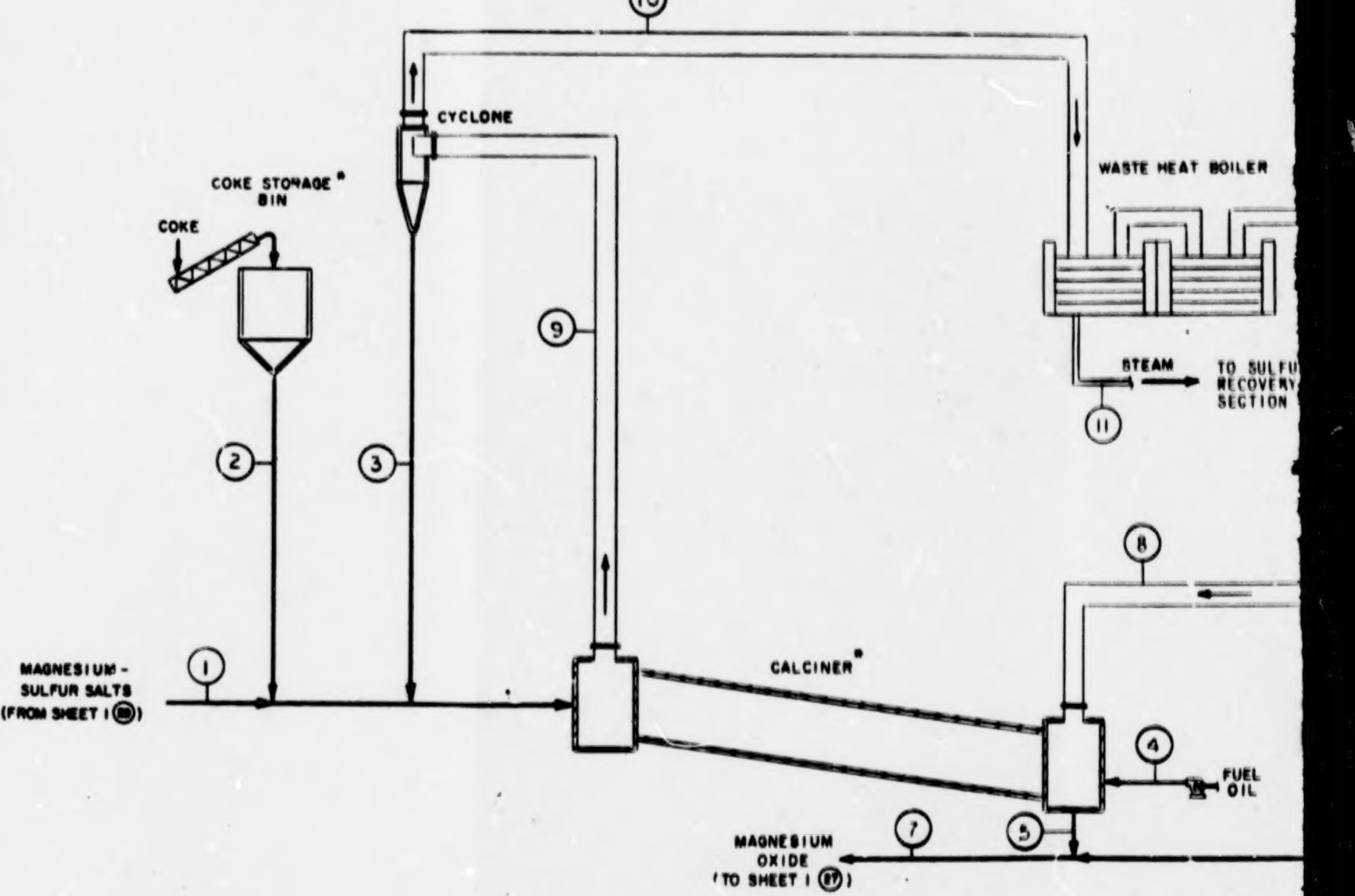
If the dryer product is processed on site it is conveyed to the Rotary Calciner, to which carbon as coke is also added, where the magnesium salts are dissociated into MgO and SO_2, in accordance with the following chemical reactions:

$$MgSO_3 + \quad Heat \longrightarrow MgO + SO_2$$

$$MgSO_4 + 1/2C \quad Heat \longrightarrow MgO + SO_2 + 1/2\ CO_2$$

The calciner exit gas, rich in SO_2 (15-17% by volume) enters a Cyclone Dust Collector followed by a Waste Heat Boiler and a Baghouse for final cleaning of the gas. The separated MgO dust is returned to the slaking system on Sheet 1 as is the solid MgO product of the calciner.

The SO_2 gas stream may be processed directly to sulfuric acid (CASE D3), or to intermediate products, sulfur dioxide or elementary sulfur.


⑩
CYCLONE
WASTE HEAT BOILER
COKE STORAGE * BIN
COKE
⑨
STEAM
TO SULFU
RECOVERY
SECTION
⑪
②
③
⑧
MAGNESIUM -
SULFUR SALTS
(FROM SHEET I [illegible])
①
CALCINER *
④
FUEL OIL
⑦
⑤
MAGNESIUM
OXIDE
(TO SHEET I (27))

SULFUR DIOXIDE RECOVERY SECTION

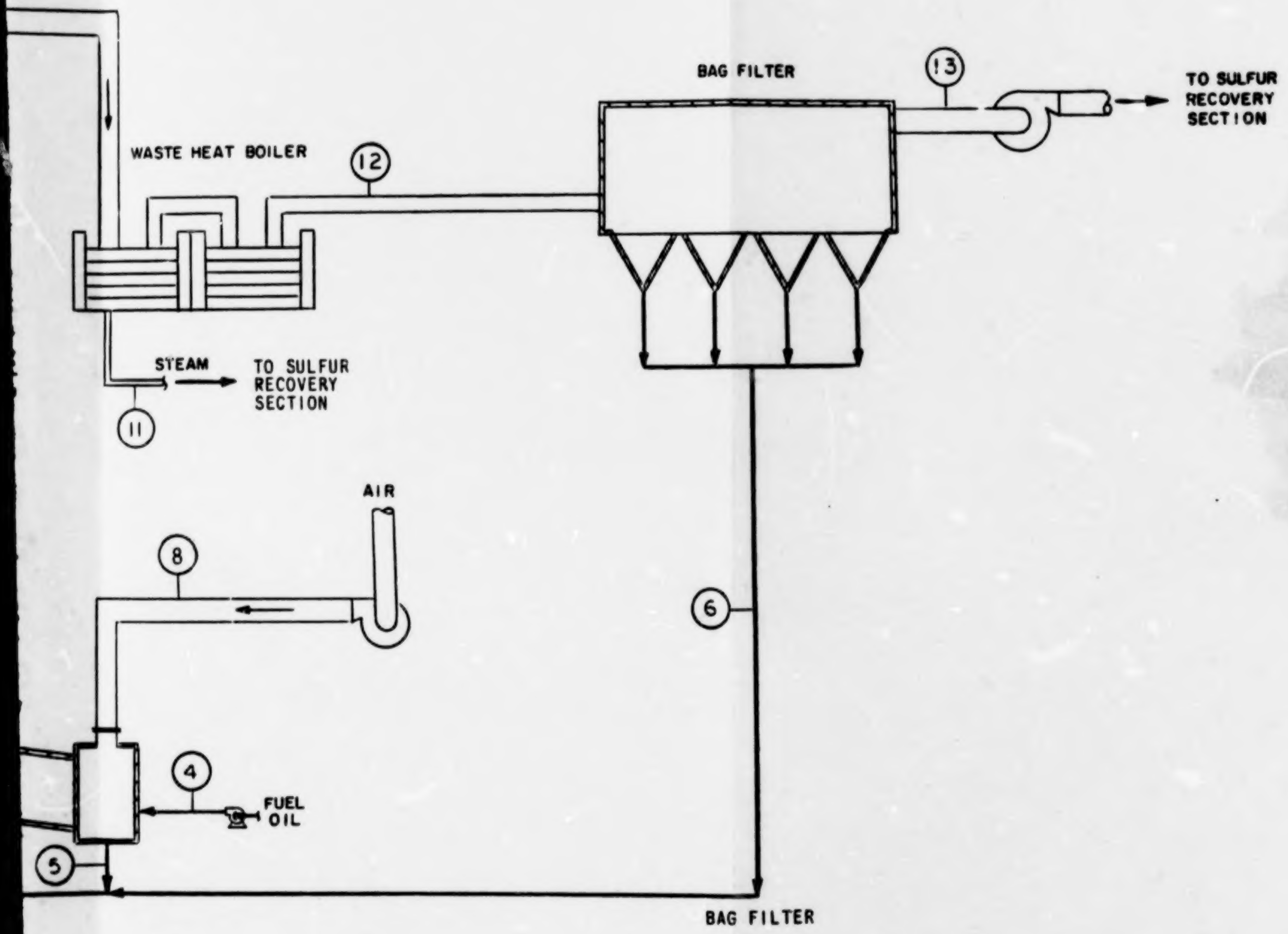
LIQUID AND SOLID STREAMS

DESIGNATION	①	②	③	④	⑤	⑥	⑦	
SOLIDS FLOW, LBS/HR	267,000	700	10,620		106,000	1,178	107.178	
TEMPERATURE °F		60						
ANHYDROUS MAGNESIUM SULFUR SALTS, LBS/HR	241,800							
MgO LBS/HR	25,150		10,620		106,000	1.178	107.178	
FUEL OIL, GPM				50.5				

GAS STREA

DESIGNATION	⑧	⑨	⑩	
VOLUME, ACFM	73,400	35 ,000	351,000	
TEMPERATURE °F	60	1500	1500	
HUMIDITY, LB/LB	0.0055	0.054	0.054	
PARTICULATE GR/SCF	0.0	14.8	1.45	
%SO$_2$	0.0	15.9	15.9	
STEAM, 550LB, SAT. LBS/HR				117,

CASE D
SHEET 2


BAG FILTER
⑬
TO SULFUR
RECOVERY
SECTION
WASTE HEAT BOILER
⑫
STEAM
TO SULFUR
RECOVERY
SECTION
⑪
AIR
⑧
⑥
④
FUEL
OIL
⑤
BAG FILTER

"THREE TRAINS

SECTION							
	GAS STREAMS						
TION	⑧	⑨	⑩	⑪	⑫	⑬	
ACFM	73,400	35 ,000	351,000		172,000	172,000	
URE°F	60	1500	1500		500	500	
, LB/LB	0.0055	0.054	0.054		0.054	0.054	
ATE	0.0	14.8	1.45		14.5	NIL	
	0.0	15.9	15.9		15.9	15.9	
OLB. HR				117,000			

HIGH SULFUR COMBUSTOR STUDY

FLOW SHEET AND QUANTITIES

——————o——————

INTERMEDIATE CHEMICAL PRODUCT

15% SULFUR DIOXIDE GAS

EQUIVALENT TO 770 TONS/DAY OF SULFUR

1.5 Reduction of SO_2 to Sulfur

The clean, cool SO_2 gas evolved from the calciner and filtered will have the following approximate composition:

	Mole %
SO_2	13
CO_2	9
H_2O	15
N_2	63
O_2	Small

This gas is compressed to 25 psig. and a portion of it combined with a gaseous reducing agent in preparation for the Claus process reduction of SO_2 to sulfur.

1.5.1 Reformed Gas

An Autothermal Reformer receives air and natural gas (essential for heat liberation) and steam and natural gas for catalytic conversion or "reforming" to a mixture of carbon monoxide and hydrogen diluted with nitrogen and small amounts of carbon dioxide and water. The base reactions are as follows:

$$2CH_4 + 3\ 1/2O_2 \longrightarrow CO_2 + 4H_2O + CO + \text{Heat}$$
$$CH_4 + H_2O + \text{Heat} \longrightarrow CO + 3H_2$$

This reducing gas is generated at about 80 psig.

1.5.2 Sulfur Dioxide to Hydrogen Sulfide

The mixture of reducing gas from atuo-thermal reforming and the controlled portion of SO_2-containing gas at 25 psig. are reacted catalytically to hydrogen sulfide and diluents in accordance with reactions as follows:

$$3H_2 + SO_2 \longrightarrow H_2S + 2H_2O \qquad (1)$$

$$3CO + SO_2 + H_2O \longrightarrow H_2S + 3CO_2 \qquad (2)$$

$$3CO + SO_2 \longrightarrow COS + 2CO_2 \qquad (3)$$

$$4H_2S + 2SO_2 \longrightarrow 3S_2 + 4H_2O \qquad (4)$$

Reactions (3) and (4) are quantitatively minor at this stage. However a net result is strong evolution of heat which is recovered in a steam boiler prior to recombining the H_2S-bearing gas with the untreated portion of the SO_2 gas stream accepted at point ① on Sheet 3.

1.5.3 Claus Reaction

The portion of the SO_2 gas stream that is diverted for reduction to H_2S is controlled as to quantity so that the mole ratio of H_2S to SO_2 in the recombined gas stream is 2. This mixture at 760° F is then reacted on the Claus bauxite catalyst essentially as follows:

$$2H_2S + SO_2 \longrightarrow 2H_2O + 3S$$

The presence of carbon compounds in the actual reaction field gives rise to carbonyl sulfide (COS) and carbon disulfide (CS_2) and these in turn react to some degree with SO_2 to yield sulfur. (See Volume One, Part VI-4.6.5). Two Claus Reactor stages with intermediate heat exchange and condensation in the first and second Sulfur Separators are provided.

From these, very high grade liquid sulfur flows to storage.

1.5.4 Incinerator

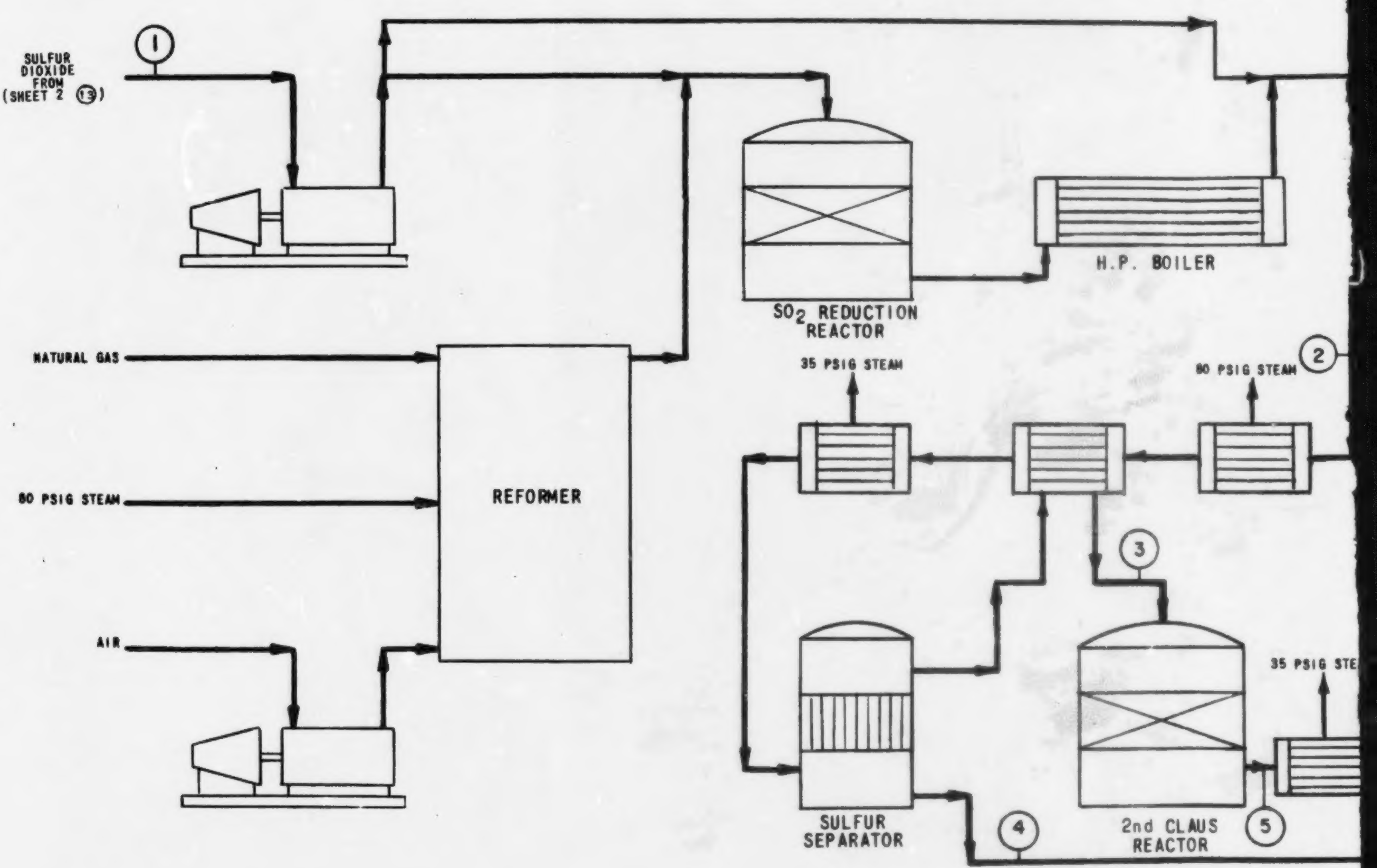
The Claus equilibria tend to yield 81.6% of theory as sulfur per pass. The exit gas of the second sulfur separator proceeds at 300°F to the Preheater of the Incinerator and into the incinerator at 740°F where all reduced sulfur compounds (H_2S, COS, CS_2 and uncondensed S) are burned in air to SO_2. Essentially 18.4% of the sulfur entering Sheet 3 as SO_2 feed gas is returned as SO_2 to the main absorber on Sheet 1, reacted therein to magnesium sulfur salts and recycled.

The SO_2 reduction plant as represented by Sheet 3 is thus effectively free of sulfur losses in the form of volatile sulfides or oxides.

1.6 Turndown Characteristics

The conversion of SO_2 in the flue gas to magnesium sulfur salts can operate at any reduced rate down to quite low levels both as to SO_2 throughput quantity and flue gas concentration but of course at reduced efficiency. The dry magnesium salts can be bulk stored (under cover) until the calcination and reduction to sulfur can be operated at a normal rate.

At very low levels of flue gas SO_2, the main absorber can be charged with lime instead of magnesium alkali, and the precipitated lime salts discarded in the manner illustrated in CASES A, B and E.

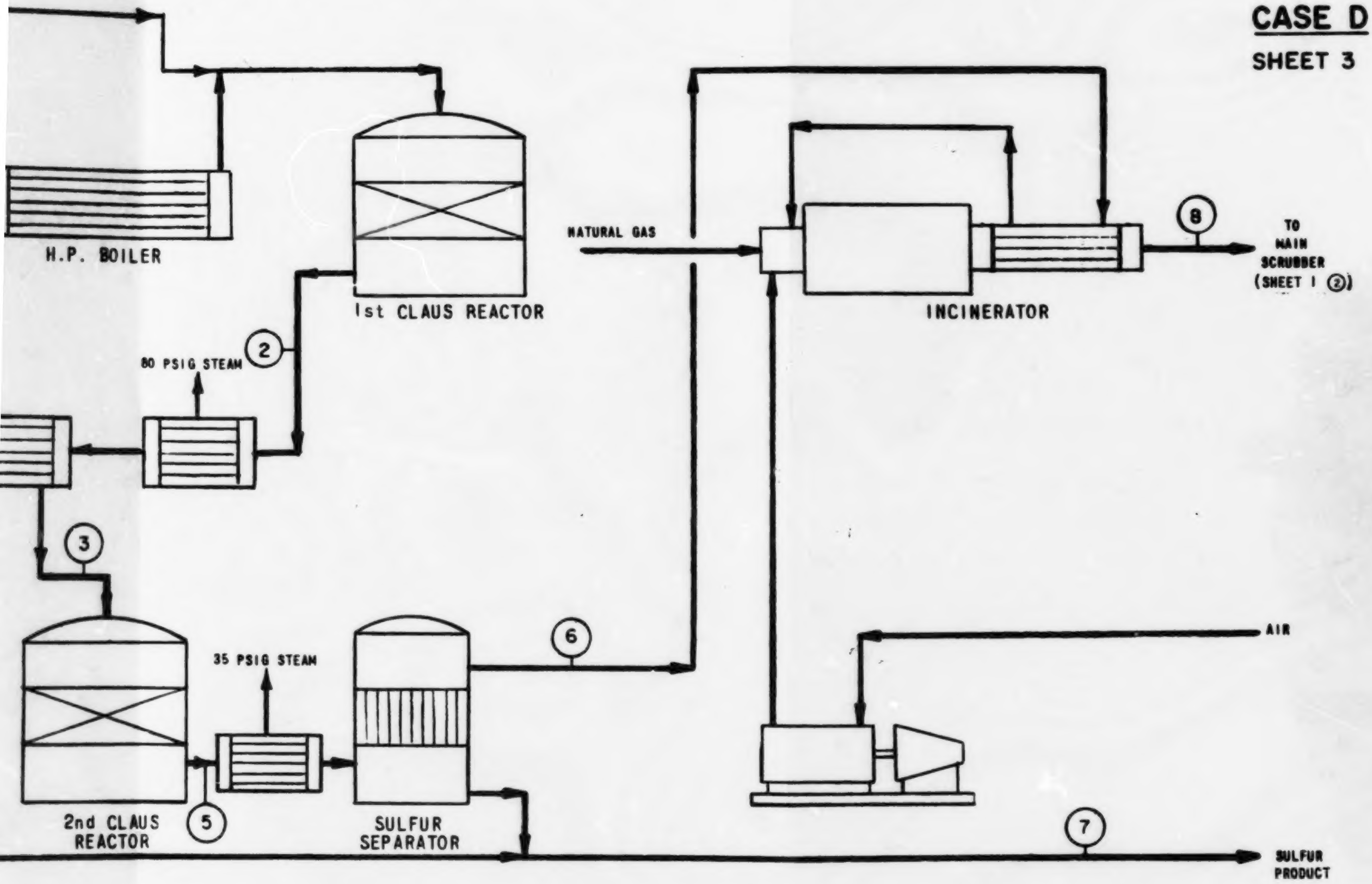

①
SULFUR DIOXIDE FROM (SHEET 2 ⑬)
NATURAL GAS
80 PSIG STEAM
AIR
REFORMER
SO_2 REDUCTION REACTOR
H.P. BOILER
35 PSIG STEAM
80 PSIG STEAM
②
③
35 PSIG STE
SULFUR SEPARATOR
④
2nd CLAUS REACTOR
⑤

PROCESS STREAM FLOWRATES FOR 770 TONS SULFUR PER DAY CAPACITY

DESIGNATION NO.	①	②	③	④	⑤	⑥	⑦	⑧
H_2S (10^3. LBS/HR)		35.4	35.4		9.1	9.1		
SO_2 "	157.2	33.3	33.3		8.4	8.4		28.9
H_2O "	50.0	142.6	142.6		156.3	156.3		173.8
H_2 "		.4	.4		.4	.4		
CO "	33.5							
SULFUR "		28.7	3.2	25.5	40.7	1.9	68.3	
INERTS "	405.0	593.8	593.8		593.8	593.8		730.1
TOTAL FLOW (10^3 LBS/HR)	612.2	834.2	808.7	25.5	808.7	769.9	64.3	932.8
ACFM	74,500	251,000	219,000		232,000	215,000		832,000
GPM				28.7			72.4	
TEMP (°F)	414	750	425	300	484	300	300	946
PRESSURE (PSIG)	25	10	6	6	4	3	3	1

CASE D

SHEET 3


H.P. BOILER
1st CLAUS REACTOR
80 PSIG STEAM
2
3
NATURAL GAS
INCINERATOR
8
TO MAIN SCRUBBER (SHEET 1 ②)
AIR
6
35 PSIG STEAM
2nd CLAUS REACTOR
5
SULFUR SEPARATOR
7
SULFUR PRODUCT

HIGH SULFUR COMBUSTOR STUDY

FLOW SHEET AND QUANTITIES

CHEMICAL PRODUCT

770 NET TONS/DAY

OF

SULFUR

2. SUMMARY OF CAPITAL COST

CASE D	Erected Cost Basis
Combustor System (See Part XI)	$15,760,000
SO$_2$ Recovery	
Dry Magnesium	$24,710,000
Calciner Plant	8,790,000
Sulfur Plant	10,500,000
	$44,000,000
Total less land	$59,760,000

XVII

CASE E SYSTEM

1. PROCESS DESCRIPTION (See CASE E data in Table XVII-1)

1.1 Fuel Milling and Combustion

An HSC Fuel of the CASE E composition (See Table XI-1) containing 13.2% iron pyrite is milled to p.c. size and conveyed by preheated air to the burners of a 500 MW utility steam boiler of a special design for integration with the Cat-Ox SO_2 recovery equipment specified for CASE E.

1.2 Flue Gas Cleaning (See Cat-Ox Flowsheet following page XVII-11)

Combustion gas containing about 0.7% SO_2 and all fly ash is conducted out of the boiler at 850° F directly into Electrostatic Precipitators by which particulate manner is removed virtually completely from the gas stream into hoppers that are periodically dumped to an ash settling pond.

1.3 Conversion of SO_2 to SO_3

The hot, clean gas passes through the Converter beds where SO_2 is oxidized on Cat-Ox A* catalyst to SO_3. A temperature rise of 25° F and conversion of 93.8% is expected with this gas strength.

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* Trademark of Monsanto Enviro-Chem Systems, Inc.

There is a gradual buildup of fly ash in the converter and thus a gradual increase in pressure drop across the unit over a period of time. While fly ash buildup does not much affect conversion efficiency, a need for catalyst cleaning four times a year is anticipated. Equipment is provided to convey mechanically, clean and return the catalyst to the converter with minor loss of material and with no loss of activity. Total downtime for this cleaning operation including catalyst cool-off, cleaning, and heat-up is estimated at two days for each converter module. The procedure requires two maintenance men each shift for three shifts to operate the catalyst handling equipment. Experience has shown that approximately 2.5% of the catalyst by volume must be added with each cleaning operation to replace losses from screening and mechanical handling.

1.4 Heat Recovery

Gas leaving the converter passes to an Air Heater where the heat in the gas is absorbed and returned to the boiler cycle. The converter exit gas is cooled to 420° F by heating the boiler combustion air to 500° F in the exchange.

The combustion gas air heater is supplemented by a Steam Air Heater which uses extraction steam from the turbine as its heat source, and a Fluid Air Heater which utilizes heat extracted from hot recirculating Product Acid. Air at ambient temperature is heated to about 300° F by these two supplementary heat exchangers before it passes through the main air heater. The Forced Draft Fans which move the combustion air through this heat absorption equipment are an integral part of the Cat-Ox system. The Induced Draft Fans which move the flue gas through the Cat-Ox system are located downstream from the air heater.

1.5 Sulfuric Acid Collection

Following heat recovery and cooling to 430° F the flue gas passes to Absorbing Towers in which the gas is brought into contact with a stream of cool sulfuric acid which condenses the newly synthesized sulfuric acid vapor in the gas stream. The heated circulating acid drains to the bottom of the tower and thence to external shell and tube heat exchangers in which it is cooled and recycled to the tower by Circulating Pumps. An acid level controller in the tower diverts a portion of the circulating acid through the Product Acid Cooler to the Storage Tank. About half of the acid heat is ultimately transferred to the combustion air as described above. The acid heat is first transferred to circulating water, the circulating water in turn preheats the air to the main air heater. The remainder of the acid is transferred directly to cooling water. The Acid Circulation Coolers are constructed of graphite tubes and steel shells. The fluid/air heaters are steel.

Very fine mist particles of sulfuric acid are formed in the gas as it is cooled in the absorbing tower. These mist particles are removed along with some entrained droplets of circulating acid in the tower by the Mist Eliminator. This unit is located in the upper section of the absorbing tower and is made of fiber-packed elements. The sulfuric acid collected by the mist eliminators is added to the circulating acid stream.

The acid produced in this system contains a small quantity of settleable solids (less than 0.1%) which is essentially fly ash. Entrained acid droplets from the absorbing section of the tower can carry these solids onto the surfaces of mist eliminator elements. With time the gradual buildup may result in increased draft loss across these elements. To overcome this and insure clean element performance, an internal water works system has been provided by which the elements may be cleaned periodically. All elements are equipped with wash piping so that all can be flushed when required and as the operators' duties permit.

1.6 Intermediate Storage

Cooled Cat-Ox acid at 60° Baume (77.7% H_2SO_4) is collected in vertical steel Storage Tanks.

1.7 Concentration of Cat-Ox Acid to 93-98% Commercial Grade, Storage and Loading

In order to apply comparable sales value criteria to the sulfuric acid product of the Cat-Ox process and the standard contact process the capital cost and operating cost estimates of XVII-4 and VIII-2 reflect the addition of drum concentrating equipment to the Cat-Ox system in order to upgrade the Cat-Ox product to 93-98% Commercial Grade Sulfuric Acid.

1.8 Tail-Gas Treating

The Cat-Ox system adapted to CASE E is designed to achieve 93.8% conversion, and SO_2 content of the gas following treatment will be 420 ppm. The bulk of this is removed before discharging to atmosphere by the addition of treating equipment similar in design and operation to that described in XIII-1.6. A single-stage venturi scrubber circulates a slurry of calcium hydroxide, calcium sulfite and calcium sulfate. The sulfur salts are settled in a thickner, the overflow is returned to the scrubbing cycle, and the underflow is centrifuged. The solids are dumped.

TABLE XVII - 1

CASE E DATA

	Clean Coal	HSC Fuel, Dry	HSC Fuel As Fired		To Cat-Ox, % Volume Dry	To Cat-Ox, % Volume Wet
Fe S_2, %		13.2	11.2	SO_2	0.70	0.66
Organic S, %		0.9	0.75	SO_3	0.02	0.02
Total S, %				O_2	4.20	4.00
Coal Combustibles, %		65.9	56.0	CO_2	15.89	15.14
Non-Pyritic Ash, %		20.0	17.0	N_2	79.19	75.46
Moisture, %			15.0	H_2O	--	4.72
Btu/Lb		9659	8210			
Fe S_2, Lb/Hr			70377	Temp., F	850	
Organic S. Lb/Hr			4704	M Lb/Hr	5871	
Coal, Lb/Hr			351446	MACFM	3081	
N-P Ash, Lb/Hr			106632	MSCFM	1157	
Moisture, Lb/Hr			94087	Fly Ash		
Total, Lb/Hr			627246	Lb/Hr	122840	
Sulfur/Coal Ratio			0.12	% Fe	21.4	
Input, MM Btu/Hr			5150			
M Tons/Year			2509			

R. E. Z.
4/30/70

2. EQUIPMENT LIST

Major pieces of equipment included in the Cat-Ox system are listed below.

ITEM	NUMBER	DESCRIPTION
Precipitators	6	High temperature, high efficiency, electrostatic precipitators. Individual units operate in parallel, independently of each other.
Converters	12	Cat-Ox converters for supporting Cat-Ox A catalyst as a fixed bed in a shell. Individual units operate in parallel but independently of each other so that any unit can be cleaned without effecting the performance of the other units. Sufficient Cat-Ox A catalyst is supplied to charge all units.
Economizers	6	Finned tube gas to liquid heat exchangers. Individual units operate in parallel, independently of each other.
Air Heaters	3	Gas to air heat exchangers. Individual units operate in parallel, independently of each other.

ITEM	NUMBER	DESCRIPTION
Forced Draft Fans	3	Centrifugal fans with direct connected 3,500 HP, 900 RPM motor drives. The units operate in parallel, one on each air heater.
Fluid/Air Heater	3	Finned tube liquid to air heat exchangers. The units operate in parallel, one on each air heater.
Steam/Air Heater	3	Finned tube steam coil air heaters. The units operate in parallel, one on each air heater.
Induced Draft Fans	6	Centrifugal fans with direct connected 3,500 HP, 1,200 RPM motor drives. The units operate in parallel but independently of each other, two on each air heater and absorbing tower combination.
Absorbing Towers - Mist Eliminators	3	Vertical, cylindrical, bricklined, packed towers. The units operate in parallel but independently of each other. The units are designed for the Cat-Ox system and each is equipped with an acid distribution system, a Cat-Ox mist eliminator and a mist eliminator wash system.

ITEM	NUMBER	DESCRIPTION
Acid Circulating Pumps	12	Centrifugal pumps with direct connected 60 HP motor drives. The units operate in parallel but independently of each other, three on each absorbing tower. Three units are active on each tower and one is an installed spare.
Acid Circulation Coolers	18	Shell and tube liquid to liquid heat exchangers. The units operate in parallel, independently of each other. Six are installed spares.
Condensate Heat Exchanger	3	Shell and tube liquid to liquid heat exchangers. The units operate in parallel, independently of one another.
Product Acid Cooler	2	Shell and tube liquid to liquid heat exchanger.
Product Acid Storage Tanks	18	Vertical, cylindrical, covered tanks 60 feet diameter, 30 feet high.
Acid Loading Pumps	2	Centrifigual pumps with motor drives are provided to load acid for shipment.
Catalyst Separators Catalyst Storage Bins Catalyst Conveyors Catalyst Elevators	1	Complete system of valves, conveyors and screens provided to unload, and clean dirty catalyst and relaod.

ITEM	NUMBER	DESCRIPTION
Fly Ash System Exhaust Water Pump	1	Pneumatic conveying system for collecting fly ash from precipitator hoppers and transporting to battery limits. Gates provided between each hopper and pneumatic conveying line.

All necessary connecting ductwork, piping, control and monitoring instrumentation, electrical work, electrical pipe heating, insulation, foundations, supports, access structures, acid loading docks, safety showers and neutralization pit are provided.

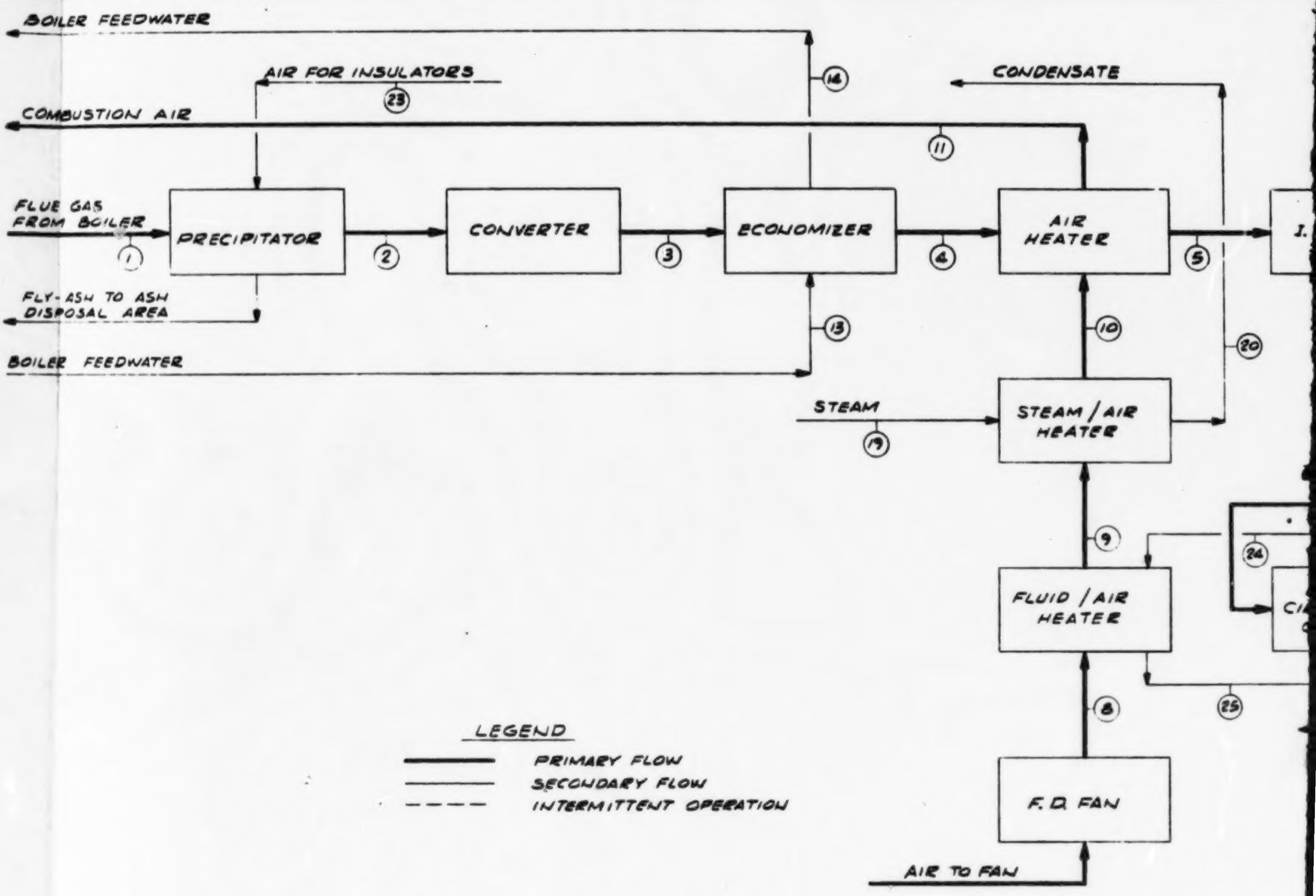
3. PROCESS AND UTILITY REQUIREMENTS

Plant design assumes that process and utility streams are supplied to the Cat-Ox system battery limits. All quantities and conditions are for full load operation.

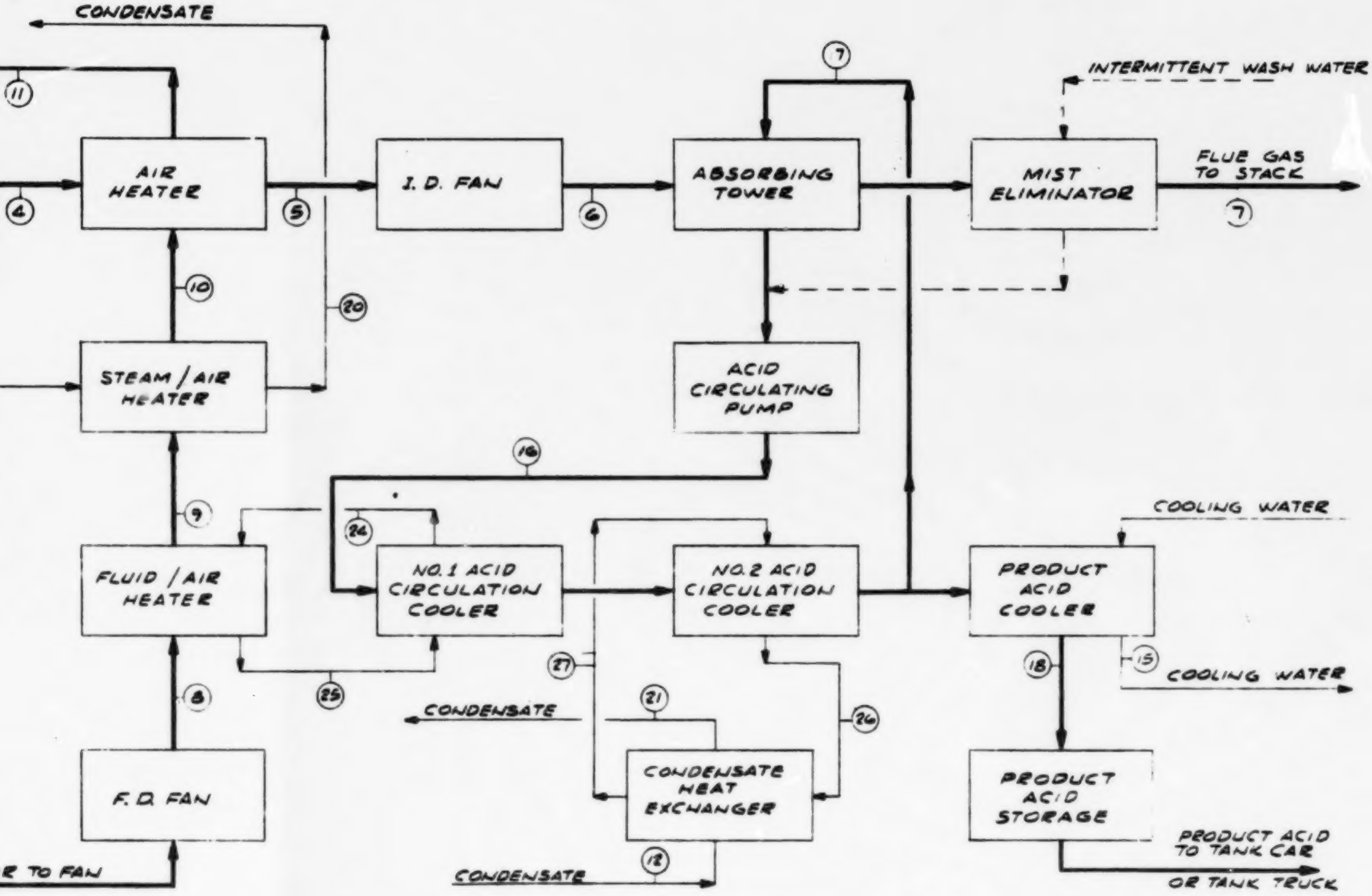
		INLET	OUTLET
3.1	Combustion Air		
	Temperature, F	80	500
	Pressure, in. of water	-----	20.0
	Quantity, Lb/Hr	-----	5,398,000
3.2	Steam* and Condensate		
	Pressure, PSIA	285	250
	Quantity, Lb/Hr	124,000	124,000
	Enthalpy, Btu/Lb	1,203	380
3.3	Boiler Feed Water		
	Temperature, F	480	575
	Pressure, PSIA	2,650	2,620
	Quantity, Lb/Hr	3,500,000	3,500,000
3.4	Cooling Water		
	Temperature, F	90	120
	Quantity, GPM	455	455
3.5	Potable Water (for Safety Showers)		
	Pressure, PSIG	75	-----
	Quantity, GPM	50	-----
3.6	Electric Power		
	3 Phase, 60 Cycle, 400, 2,300 or 4,600 Volt,		
	Connected HP	38,200	-----
	Operating KW	20,700	-----
3.7	Fly Ash		
	Quantity, Lb/Hr	-----	123,000

	INLET	OUTLET
3.8 **Sulfuric Acid**		
Temperature, F	-----	100
Strength	-----	60° Baume
Quantity, Lb/Hr	-----	156,000

*High pressure extraction steam from intermediate pressure turbine.


BOILER FEEDWATER
AIR FOR INSULATORS
23
14
CONDENSATE
COMBUSTION AIR
11
FLUE GAS FROM BOILER
1
PRECIPITATOR
2
CONVERTER
3
ECONOMIZER
4
AIR HEATER
5
I.
FLY-ASH TO ASH DISPOSAL AREA
13
10
20
BOILER FEEDWATER
STEAM
19
STEAM / AIR HEATER
9
24
FLUID / AIR HEATER
CI
25
8
LEGEND
PRIMARY FLOW
SECONDARY FLOW
INTERMITTENT OPERATION
F. D. FAN
AIR TO FAN

STREAM Nº	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
STREAM PROPERTY	FLUE GAS	FLUE GAS TO CONV.	FLUE GAS TO ECON.	FLUE GAS TO AIR HTR.	FLUE GAS TO I.D FAN	FLUE GAS TO ABSORB. TOWER	FLUE GAS TO STACK	AIR TO FLUID/ AIR HTR.	AIR TO STEAM/ AIR HTR.	AIR TO AIR HTR.	COMBUST. AIR	CONDENSATE	BOILER FDWATER TO ECON.	FDWATER TO BOILER	COOLING WATER	ACID TO ACID/CIRC. COOLERS	ACID TO ABSORB. TOWER	PRODUCT ACID	ST


CONDENSATE
11
AIR HEATER
4
5
I. D. FAN
6
7
ABSORBING TOWER
INTERMITTENT WASH WATER
MIST ELIMINATOR
FLUE GAS TO STACK
7
10
20
STEAM / AIR HEATER
ACID CIRCULATING PUMP
16
9
24
FLUID / AIR HEATER
NO. 1 ACID CIRCULATION COOLER
NO. 2 ACID CIRCULATION COOLER
COOLING WATER
PRODUCT ACID COOLER
18
15
COOLING WATER
8
25
27
CONDENSATE
21
26
F. D. FAN
CONDENSATE HEAT EXCHANGER
PRODUCT ACID STORAGE
PRODUCT ACID TO TANK CAR OR TANK TRUCK
R TO FAN
CONDENSATE
12

13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
OILER DWATER TO ECON.	FDWATER TO BOILER	COOLING WATER	ACID TO ACID/CIRC. COOLERS	ACID TO ABSORB. TOWER	PRODUCT ACID	STEAM TO STEAM/ AIR HTR.	CONDEN-SATE TO FDWATER HTR.	CONDEN-SATE	FUEL TO BOILER	AIR FOR INSUL-ATORS	FLUID TO FLUID/AIR HEATER	FLUID TO ACID CIRC. COOLER	FLUID TO COND. HT. EXGR.	FLUID TO ACID CIRC COOLER

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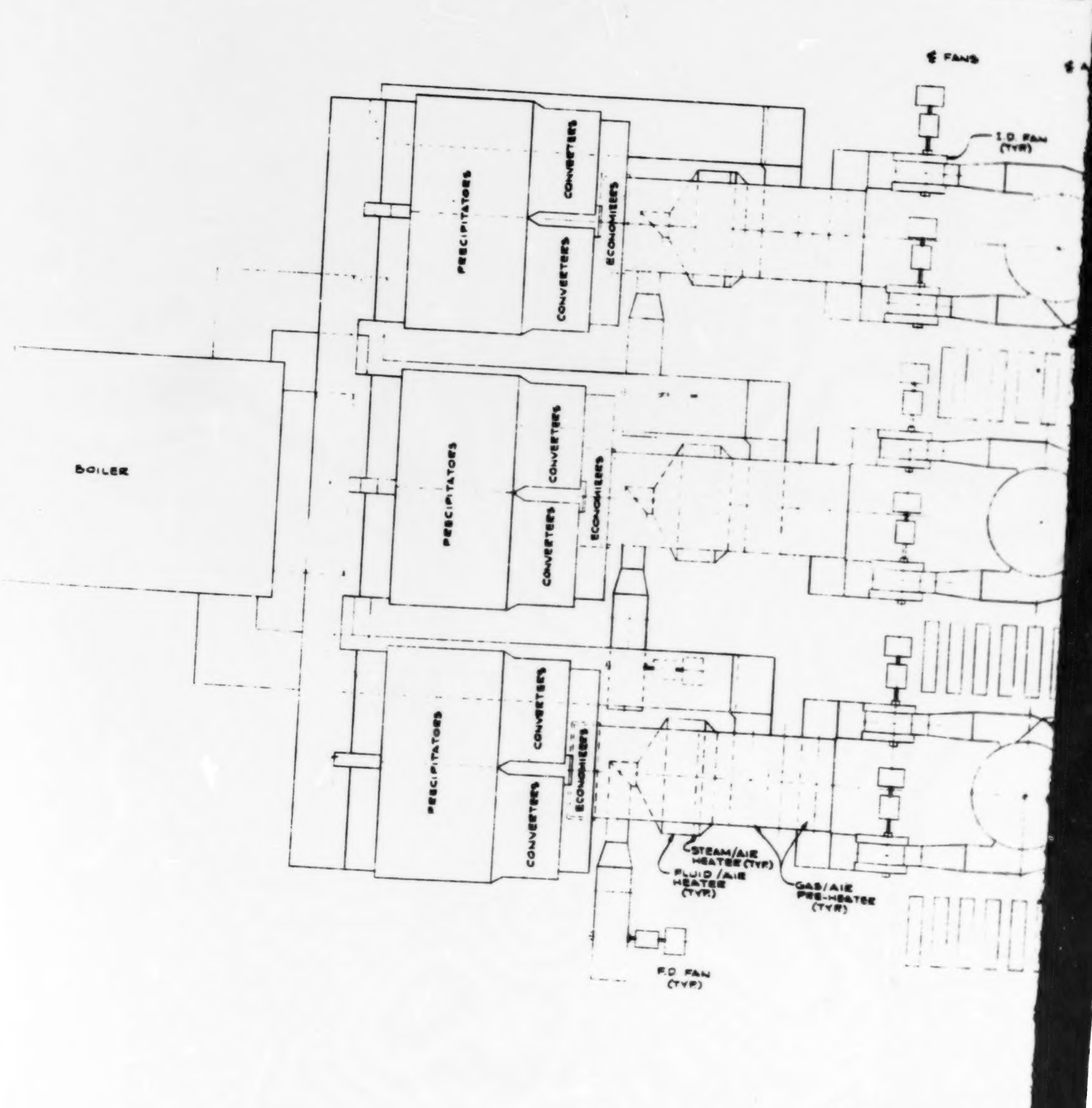
NO.	DATE	REVISIONS	BY

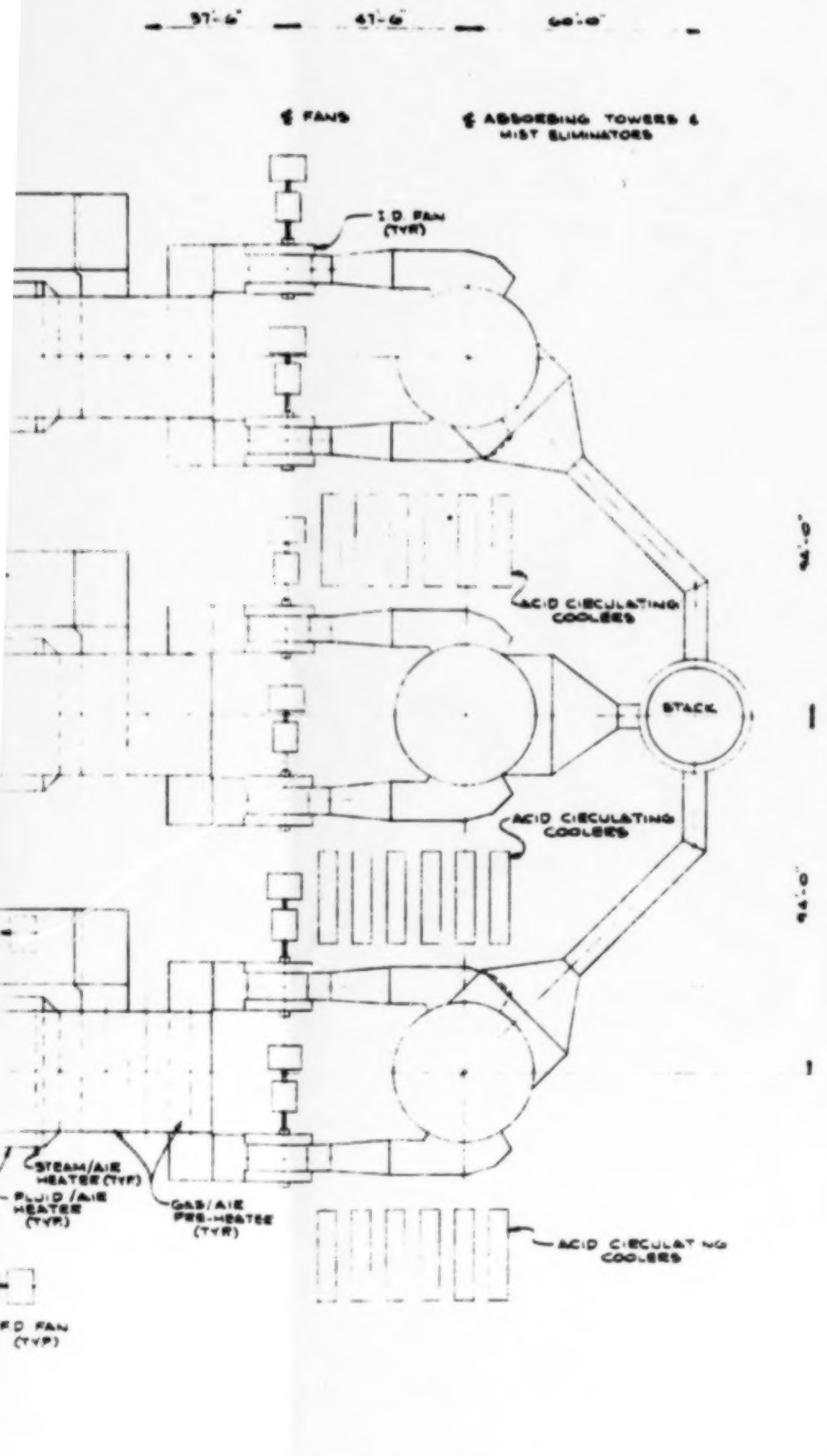
Monsanto Enviro-Chem
MONSANTO ENVIRO-CHEM SYSTEMS INC.
10 S. RIVERSIDE PLAZA
CHICAGO, ILLINOIS 60606

CHEMICO/NAPCA STUDY COAL BENEFICIATION PLANT

STREAM FLOW DIAGRAM
INTEGRATED CAT-OX SYSTEM
CASE-"E" 500MW

	BY	DATE	APPROVED	DATE	JOB NO.
DRAWN	R.S. GAYDOS	6/2/72	T-S	6-2-72	0694
CHECKED	R.H.	6/2/72	[illegible]	6-2-72	DWG NO. 3-20
SCALE			R.R.Y.	6-3-72	


37'-6"
47'-6"
℄ FANS
I.D. FAN (TYP)
PRECIPITATORS
CONVERTERS
CONVERTERS
ECONOMIZERS
BOILER
PRECIPITATORS
CONVERTERS
CONVERTERS
ECONOMIZERS
PRECIPITATORS
CONVERTERS
CONVERTERS
ECONOMIZERS
STEAM/AIR HEATER (TYP)
FLUID/AIR HEATER (TYP)
GAS/AIR PRE-HEATER (TYP)
F.D. FAN (TYP)
SCALE IN FEET
0
50


37'-6"
41'-6"
60'-0"
℄ FANS
℄ ABSORBING TOWERS & MIST ELIMINATORS
I.D. FAN (TYP)
ACID CIRCULATING COOLERS
STACK
ACID CIRCULATING COOLERS
94'-0"
94'-0"
STEAM/AIR HEATER (TYP)
FLUID/AIR HEATER (TYP)
GAS/AIR PRE-HEATER (TYP)
ACID CIRCULATING COOLERS
F.D. FAN (TYP)
SCALE IN FEET
0
50
100

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[illegible]

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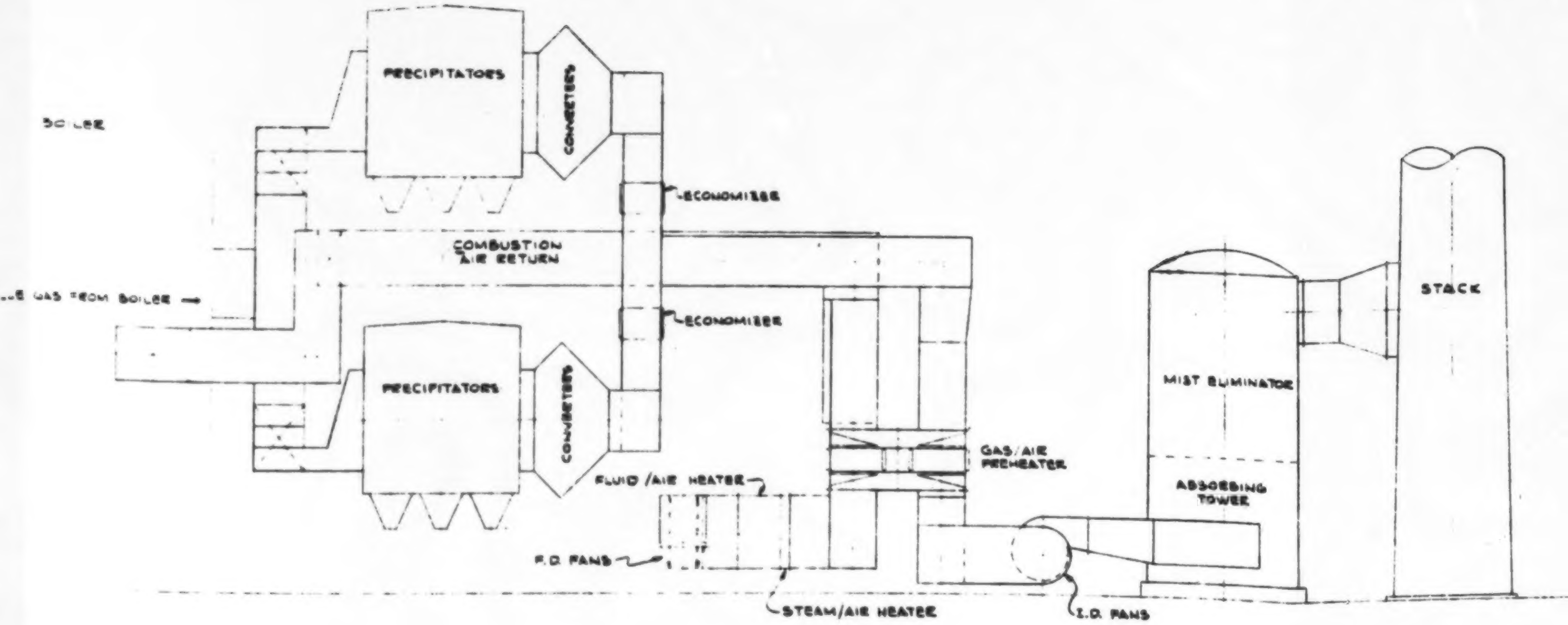
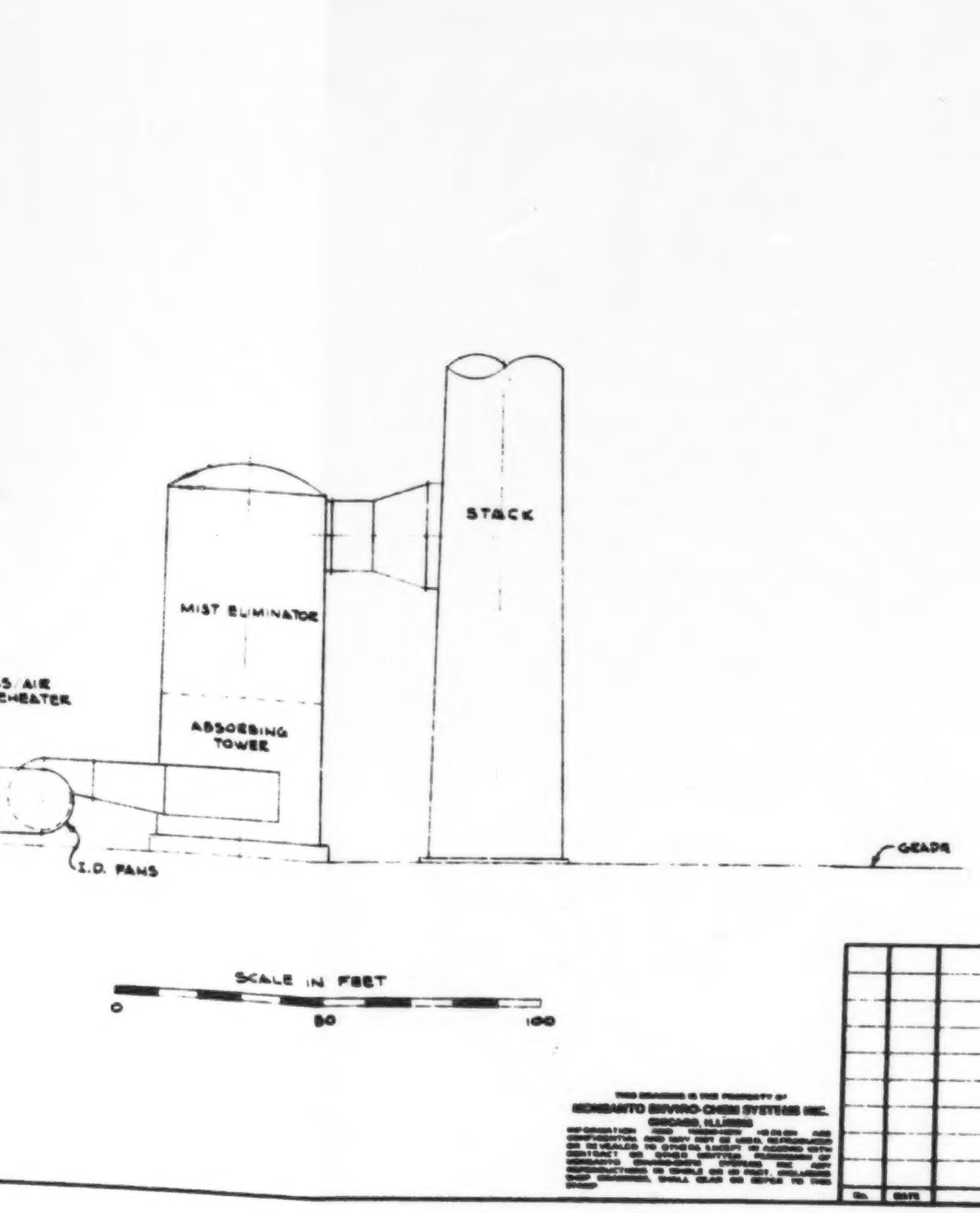
CHICAGO, ILLINOIS 60606

CHEMICO, NAPCA STUDY COAL BENEFICIATION PLANT
PLANT LAYOUT - PLAN
INTEGRATED CAT-OX SYSTEM
CASE - E 500 MW

	BY	DATE	APPROVAL	DATE	
DRAWN	P.S. GAYDOS	[illegible]	[illegible]	[illegible]	-0694
CHECKED	[illegible]	[illegible]	[illegible]	[illegible]	- 3-21
SCALE	1"=20'-0"				


BOILER
E GAS FROM BOILER →
PRECIPITATORS
CONVERTERS
ECONOMIZER
COMBUSTION AIR RETURN
ECONOMIZER
PRECIPITATORS
CONVERTERS
FLUID/AIR HEATER
GAS/AIR PREHEATER
F.D. FANS
STEAM/AIR HEATER
I.D. FANS
MIST ELIMINATOR
ABSORBING TOWER
STACK
SCALE IN FEET
0
50
100


STACK
MIST ELIMINATOR
S/AIR
EHEATER
ABSORBING
TOWER
I.D. FANS
GRADE
SCALE IN FEET
0
50
100

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NO.	DATE	REVISIONS	BY

Enviro-Chem

MONSANTO ENVIRO-CHEM SYSTEMS INC.
10 S. RIVERSIDE PLAZA
CHICAGO, ILLINOIS 60606

CHEMICO/NAPCA STUDY COAL BENEFICIATION PLANT

PLANT LAYOUT - ELEVATION
INTEGRATED CAT-OX SYSTEM

CASE - E 500 MW

	BY	DATE	APPROVED	DATE	
DRAWN	R S GAVERS	[illegible]	T.S.	[illegible]	JOB NO. 0694
CHECKED	A.K.	[illegible]	[illegible]	[illegible]	DWG NO. 3-22
SCALE	1" = 20'-0"		[illegible]	[illegible]	

4. Cat-Ox CAPITAL COST

"The approximate total capital cost for an integrated Cat-Ox system for the specified conditions and with a Scope of Supply as listed in the Preliminary Scope Report, based on current labor rates, is $31,000,000 installed.

"Certain equipment items are included in the Cat-Ox system which are also included in the boiler scope and pricing. The boiler pricing you are obtaining from Foster Wheeler includes forced draft fan, air heater, and flues and ducts to the air heater. These items are also included in the Cat-Ox system total cost above. The approximately installed cost of this "overlapping" equipment, based on current labor rates, is $4,000,000. Thus, the incremental approximate capital cost of Cat-Ox for this application is $27,000,000. "--- Monsanto Enviro-Chem Systems, Inc. Preliminary Scope Report, CASE E June 12, 1970.

The advice cited above is given effect in the capital cost estimate of CASE E that is entered in Volume One, Table VIII-1 as shown below.

CASE E	Erected Cost Basis
Combustor/Boiler	$15,760,000
Adjustment for "overlapping" equipment	4,000,000
Net Combustor/Boiler	$11,760,000
Cat-Ox Acid Plant	31,000,000
Acid Concentrators	8,000,000
Tail-Gas Treatment	6,700,000
Sulfur Recovery Total	$45,700,000
Total less land	$67,460,000